Year book

Carnegie Institution of Washington

[redacted]

CARNEGIE INSTITUTION

OF

WASHINGTON

YEAR BOOK No. 13

1914

PUBLISHED BY THE INSTITUTION
WASHINGTON, U. S. A.

WASHINGTON, D. C.
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139

OFFICERS FOR THE YEAR 1915.

President of the Institution.

ROBERT S. WOODWARD.

Trustees.

Executive Committee.

Finance Committee.

Auditing Committee.

*Ex-officio member.

LIST OF PRESENT AND FORMER TRUSTEES.

Besides the names enumerated above, the following were ex-officio members of the Board of Trustees under the original charter, from the date of organization until April 28, 1904:

The President of the United States.
The President of the Senate.
The Speaker of the House of Representatives.
The Secretary of the Smithsonian Institution.
The President of the National Academy of Sciences.

CONTENTS.

LIST OF ILLUSTRATIONS.

ORGANIZATION, PLAN AND SCOPE.

The Carnegie Institution of Washington was founded by Mr. Andrew Carnegie, January 28, 1902, when he gave to a board of trustees an endowment of registered bonds of the par value of ten million dollars. To this fund an addition of two million dollars was made by Mr. Carnegie on December 10, 1907, and a further addition of ten million dollars was made by him January 19, 1911; so that the present endowment of the Institution has a par value of twenty-two million dollars. The Institution was originally organized under the laws of the District of Columbia and incorporated as the *Carnegie Institution*, articles of incorporation having been executed on January 4, 1902. The Institution was reincorporated, however, by an act of the Congress of the United States, approved April 28, 1904, under the title of *The Carnegie Institution of Washington*. (See existing Articles of Incorporation on the following pages.)

Organization under the new Articles of Incorporation was effected May 18, 1904, and the Institution was placed under the control of a board of twenty-four trustees, all of whom had been members of the original corporation. The trustees meet annually in December to consider the affairs of the Institution in general, the progress of work already undertaken, the initiation of new projects, and to make the necessary appropriations for the ensuing year. During the intervals between the meetings of the Trustees the affairs of the Institution are conducted by an Executive Committee chosen by and from the Board of Trustees and acting through the President of the Institution as chief executive officer.

The Articles of Incorporation of the Institution declare in general "that the objects of the corporation shall be to encourage, in the broadest and most liberal manner, investigation, research, and discovery, and the application of knowledge to the improvement of mankind." Three principal agencies to forward these objects have been developed. The first of these involves the establishment of departments of research within the Institution itself, to attack larger problems requiring the collaboration of several investigators, special equipment, and continuous effort. The second provides means whereby individuals may undertake and carry to completion investigations not less important but requiring less collaboration and less special equipment. The third agency, namely, a division devoted to editing and to printing books, aims to provide adequate publication of the results of research coming from the first two agencies and to a limited extent also for worthy works not likely to be published under other auspices.

ARTICLES OF INCORPORATION.

Public No. 260.—An Act To incorporate the Carnegie Institution of Washington.

Be in enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the persons following, being persons who are now trustees of the Carnegie Institution, namely, Alexander Agassiz, John S. Billings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Lyman J. Gage, Daniel C. Gilman, John Hay, Henry L. Higginson, William Wirt Howe, Charles L. Hutchinson, Samuel P. Langley, William Lindsay, Seth Low, Wayne MacVeagh, Darius O. Mills, S. Weir Mitchell, William W. Morrow, Ethan A. Hitchcock, Elihu Root, John C. Spooner, Andrew D. White, Charles D. Walcott, Carroll D. Wright, their associates and successors, duly chosen, are hereby incorporated and declared to be a body corporate by the name of the Carnegie Institution of Washington and by that name shall be known and have perpetual succession, with the powers, limitations, and restrictions herein contained.

Sec. 2. That the objects of the corporation shall be to encourage, in the broadest and most liberal manner, investigation, research, and discovery, and the application of knowledge to the improvement of mankind; and in particular—

(a) To conduct, endow, and assist investigation in any department of science, literature, or art, and to this end to cooperate with governments, universities, colleges, technical schools, learned societies, and individuals.

(b) To appoint committees of experts to direct special lines of research.

(c) To publish and distribute documents.

(d) To conduct lectures, hold meetings and acquire and maintain a library.

(e) To purchase such property, real or personal, and construct such building or buildings as may be necessary to carry on the work of the corporation.

(f) In general, to do and perform all things necessary to promote the objects of the institution, with full power, however, to the trustees hereinafter appointed and their successors from time to time to modify the conditions and regulations under which the work shall be carried on, so as to secure the application of the funds in the manner best adapted to the conditions of the time, provided that the objects of the corporation shall at all times be among the foregoing or kindred thereto.

Sec. 3. That the direction and management of the affairs of the corporation and the control and disposal of its property and funds shall be vested in a board of trustees, twenty-two in number, to be composed of the following individuals: Alexander Agassiz, John S. Billings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Lyman J. Gage, Daniel C. Gilman, John Hay, Henry L. Higginson, William Wirt Howe, Charles L. Hutchinson, Samuel P. Langley, William Lindsay, Seth Low, Wayne MacVeagh, Darius O. Mills, S. Weir Mitchell, William W. Morrow, Ethan A. Hitchcock, Elihu Root, John C. Spooner, Andrew D. White, Charles D. Walcott, Carroll D.

Wright, who shall constitute the first board of trustees. The board of trustees shall have power from time to time to increase its membership to not more than twenty-seven members. Vacancies occasioned by death, resignation, or otherwise shall be filled by the remaining trustees in such manner as the by-laws shall prescribe; and the persons so elected shall thereupon become trustees and also members of the said corporation. The principal place of business of the said corporation shall be the city of Washington, in the District of Columbia.

SEC. 4. That such board of trustees shall be entitled to take, hold and administer the securities, funds, and property so transferred by said Andrew Carnegie to the trustees of the Carnegie Institution and such other funds or property as may at any time be given, devised, or bequeathed to them, or to such corporation, for the purposes of the trust; and with full power from time to time to adopt a common seal, to appoint such officers, members of the board of trustees or otherwise, and such employees as may be deemed necessary in carrying on the business of the corporation, at such salaries or with such remuneration as they may deem proper; and with full power to adopt by-laws from time to time and such rules or regulations as may be necessary to secure the safe and convenient transaction of the business of the corporation; and with full power and discretion to deal with and expend the income of the corporation in such manner as in their judgment will best promote the objects herein set forth and in general to have and use all powers and authority necessary to promote such objects and carry out the purposes of the donor. The said trustees shall have further power from time to time to hold as investments the securities hereinabove referred to so transferred by Andrew Carnegie, and any property which has been or may be transferred to them or such corporation by Andrew Carnegie or by any other person, persons, or corporation, and to invest any sums or amounts from time to time in such securities and in such form and manner as are permitted to trustees or to charitable or literary corporations for investment, according to the laws of the States of New York, Pennsylvania, or Massachusetts, or in such securities as are authorized for investment by the said deed of trust so executed by Andrew Carnegie, or by any deed of gift or last will and testament to be hereafter made or executed.

SEC. 5. That the said corporation may take and hold any additional donations, grants, devises, or bequests which may be made in further support of the purposes of the said corporation, and may include in the expenses thereof the personal expenses which the trustees may incur in attending meetings or otherwise in carrying out the business of the trust, but the services of the trustees as such shall be gratuitous.

SEC. 6. That as soon as may be possible after the passage of this Act a meeting of the trustees hereinbefore named shall be called by Daniel C. Gilman, John S. Billings, Charles D. Walcott, S. Weir Mitchell, John Hay, Elihu Root, and Carroll D. Wright, or any four of them, at the city of Washington, in the District of Columbia, by notice served in person or by mail addressed to each trustee at his place of residence; and the said trustees, or a majority thereof, being assembled, shall organize and proceed to adopt by-laws, to elect officers and appoint committees, and generally to organize the said corporation; and said trustees herein named, on behalf of the corpora-

tion hereby incorporated, shall thereupon receive, take over, and enter into possession, custody, and management of all property, real or personal, of the corporation heretofore known as the Carnegie Institution, incorporated, as hereinbefore set forth under "An Act to establish a Code of Law for the District of Columbia, January fourth, nineteen hundred and two," and to all its rights, contracts, claims, and property of any kind or nature; and the several officers of such corporation, or any other person having charge of any of the securities, funds, real or personal, books or property thereof, shall, on demand, deliver the same to the said trustees appointed by this Act or to the persons appointed by them to receive the same; and the trustees of the existing corporation and the trustees herein named shall and may take such other steps as shall be necessary to carry out the purposes of this Act.

SEC. 7. That the rights of the creditors of the said existing corporation known as the Carnegie Institution shall not in any manner be impaired by the passage of this Act, or the transfer of the property hereinbefore mentioned, nor shall any liability or obligation for the payment of any sums due or to become due, or any claim or demand, in any manner or for any cause existing against the said existing corporation, be released or impaired; but such corporation hereby incorporated is declared to succeed to the obligations and liabilities and to be held liable to pay and discharge all of the debts, liabilities, and contracts of the said corporation so existing to the same effect as if such new corporation had itself incurred the obligation or liability to pay such debt or damages, and no such action or proceeding before any court or tribunal shall be deemed to have abated or been discontinued by reason of the passage of this Act.

SEC. 8. That Congress may from time to time alter, repeal, or modify this Act of incorporation, but no contract or individual right made or acquired shall thereby be divested or impaired.

SEC. 9. That this Act shall take effect immediately.

Approved, April 28, 1904.

BY-LAWS OF THE INSTITUTION.

Adopted December 13, 1904. Amended December 13, 1910, and December 13, 1912.

Article I.

THE TRUSTEES.

1. The Board of Trustees shall consist of twenty-four members, with power to increase its membership to not more than twenty-seven members The Trustees shall hold office continuously and not for a stated term.

2. In case any Trustee shall fail to attend three successive annual meetings of the Board he shall thereupon cease to be a Trustee.

3. No Trustee shall receive any compensation for his services as such.

4. All vacancies in the Board of Trustees shall be filled by the Trustees by ballot. Sixty days prior to an annual or a special meeting of the Board, the President shall notify the Trustees by mail of the vacancies to be filled and each Trustee may submit nominations for such vacancies. A list of the persons so nominated, with the names of the proposers, shall be mailed to the Trustees thirty days before the meeting, and no other nominations shall be received at the meeting except with the unanimous consent of the Trustees present. Vacancies shall be filled from the persons thus nominated, but no person shall be declared elected unless he receives the votes of two-thirds of the Trustees present.

Article II.

MEETINGS.

1. The annual meeting of the Board of Trustees shall be held in the City of Washington, in the District of Columbia, on the first Friday following the second Thursday of December in each year.

2. Special meetings of the Board may be called by the Executive Committee by notice served personally upon, or mailed to the usual address of, each Trustee twenty days prior to the meeting.

3. Special meetings shall, moreover, be called in the same manner by the Chairman upon the written request of seven members of the Board.

Article III.

OFFICERS OF THE BOARD.

1. The officers of the Board shall be a Chairman of the Board, a Vice-Chairman, and a Secretary, who shall be elected by the Trustees, from the members of the Board, by ballot to serve for a term of three years. All vacancies shall be filled by the Board for the unexpired term; provided, however, that the Executive Committee shall have power to fill a vacancy in the office of Secretary to serve until the next meeting of the Board of Trustees.

2. The Chairman shall preside at all meetings and shall have the usual powers of a presiding officer.

3. The Vice-Chairman, in the absence or disability of the Chairman, shall perform his duties.

4. The Secretary shall issue notices of meetings of the Board, record its transactions, and conduct that part of the correspondence relating to the Board and to his duties. He shall execute all deeds, contracts or other instruments on behalf of the corporation, when duly authorized.

Article IV.

EXECUTIVE ADMINISTRATION.

The President.

1. There shall be a President who shall be elected by ballot by, and hold office during the pleasure of, the Board, who shall be the chief executive officer of the Institution. The President, subject to the control of the Board and the Executive Committee, shall have general charge of all matters of administration and supervision of all arrangements for research and other work undertaken by the Institution or with its funds. He shall devote his entire time to the affairs of the Institution. He shall prepare and submit to the Board of Trustees and to the Executive Committee plans and suggestions for the work of the Institution, shall conduct its general correspondence and the correspondence with applicants for grants and with the special advisers of the Committee, and shall present his recommendations in each case to the Executive Committee for decision. All proposals and requests for grants shall be referred to the President for consideration and report. He shall have power to remove and appoint subordinate employees and shall be *ex officio* a member of the Executive Committee.

2. He shall be the legal custodian of the seal and of all property of the Institution whose custody is not otherwise provided for. He shall affix the seal of the corporation whenever authorized to do so by the Board of Trustees or by the Executive Committee or by the Finance Committee. He shall be responsible for the expenditure and disbursement of all funds of the Institution in accordance with the directions of the Board and of the Executive Committee, and shall keep accurate accounts of all receipts and disbursements. He shall submit to the Board of Trustees at least one month before its annual meeting in December a written report of the operations and business of the Institution for the preceding fiscal year with his recommendations for work and appropriations for the succeeding fiscal year, which shall be forthwith transmitted to each member of the Board.

3. He shall attend all meetings of the Board of Trustees.

Article V.

COMMITTEES.

1. There shall be the following standing Committees, viz., an Executive Committee, a Finance Committee, and an Auditing Committee.

2. The Executive Committee shall consist of the Chairman and Secretary of the Board of Trustees and the President of the Institution *ex officio* and, in addition, five trustees to be elected by the Board by ballot for a term of three years, who shall be eligible for re-election. Any member elected to fill a vacancy shall serve for the remainder of his predecessor's term: Provided, however, that of the Executive Committee first elected after the adoption of these by-laws two shall serve for one year, two shall serve for two years, and one shall serve for three years; and such Committee shall determine their respective terms by lot.

3. The Executive Committee shall, when the Board is not in session and has not given specific directions, have general control of the administration of the affairs of the corporation and general supervision of all arrangements for administration, research, and other matters undertaken or promoted by the Institution; shall appoint advisory committees for specific duties; shall determine all payments and salaries; and keep a written record of all transactions and expenditures and submit the same to the Board of Trustees at each meeting, and it shall also submit to the Board of Trustees a printed or typewritten report of each of its meetings, and at the annual meeting shall submit to the Board a report for publication.

4. The Executive Committee shall have general charge and control of all appropriations made by the Board.

5. The Finance Committee shall consist of three members to be elected by the Board of Trustees by ballot for a term of three years.

6. The Finance Committee shall have custody of the securities of the corporation and general charge of its investments and invested funds, and shall care for and dispose of the same subject to the directions of the Board of Trustees. It shall consider and recommend to the Board from time to time such measures as in its opinion will promote the financial interests of the Institution, and shall make a report at each meeting of the Board.

7. The Auditing Committee shall consist of three members to be elected by the Board of Trustees by ballot for a term of three years.

8. The Auditing Committee shall, before each annual meeting of the Board of Trustees, examine the accounts of business transacted under the Finance Committee and the Executive Committee. They may avail themselves at will of the services and examination of the Auditor appointed by the Board of Trustees. They shall report to the Board upon the collection of moneys to which the Institution is entitled, upon the investment and reinvestment of principal, upon the conformity of expenditures to appropriations, and upon the system of bookkeeping, the sufficiency of the accounts, and the safety and economy of the business methods and safeguards employed.

9. All vacancies occurring in the Executive Committee and the Finance Committee shall be filled by the Trustees at the next regular meeting. In case of vacancy in the Finance Committee or the Auditing Committee, upon request of the remaining members of such committee, the Executive Committee may fill such vacancy by appointment until the next meeting of the Board of Trustees.

10. The terms of all officers and of all members of committees shall continue until their successors are elected or appointed.

Article VI.

FINANCIAL ADMINISTRATION.

1. No expenditure shall be authorized or made except in pursuance of a previous appropriation by the Board of Trustees.

2. The fiscal year of the Institution shall commence on the first day of November in each year.

3. The Executive Committee, at least one month prior to the annual meeting in each year, shall cause the accounts of the Institution to be audited by a skilled accountant, to be appointed by the Board of Trustees, and shall submit to the annual meeting of the Board a full statement of the finances and work of the Institution and a detailed estimate of the expenditures for the succeeding year.

4. The Board of Trustees, at the annual meeting in each year, shall make general appropriations for the ensuing fiscal year; but nothing contained herein shall prevent the Board of Trustees from making special appropriations at any meeting.

5. The securities of the Institution and evidences of property, and funds invested and to be invested, shall be deposited in such safe depository or in the custody of such trust company and under such safeguards as the Trustees and Finance Committee shall designate; and the income available for expenditure of the Institution shall be deposited in such banks or depositories as may from time to time be designated by the Executive Committee.

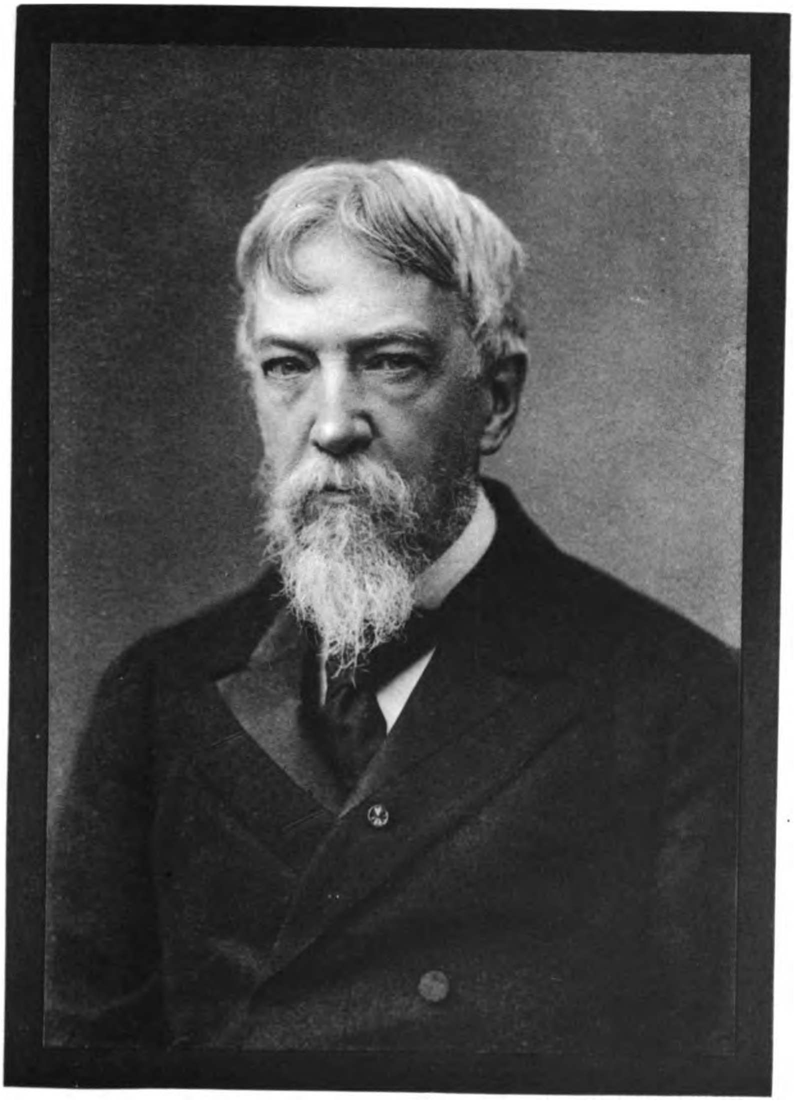
6. Any trust company entrusted with the custody of securities by the Finance Committee may, by resolution of the Board of Trustees, be made Fiscal Agent of the Institution, upon an agreed compensation, for the transaction of the business coming within the authority of the Finance Committee.

Article VII.

AMENDMENT OF BY-LAWS.

1. These by-laws may be amended at any annual or special meeting of the Board of Trustees by a two-thirds vote of the members present, provided written notice of the proposed amendment shall have been served personally upon, or mailed to the usual address of, each member of the Board twenty days prior to the meeting.

PLATE 1



WEIR MITCHELL
1829-1914

MINUTES

OF THE

THIRTEENTH MEETING OF THE BOARD OF TRUSTEES

ABSTRACT OF MINUTES OF THIRTEENTH MEETING OF BOARD OF TRUSTEES.

The meeting was held in Washington, in the Board Room of the Administration Building, on Friday, December 11, 1914, and was called to order at 10 o'clock a. m. by the chairman, Mr. Root.

Upon roll-call by the secretary, the following Trustees responded: Robert S. Brookings, Cleveland H. Dodge, Henry L. Higginson, Charles L. Hutchinson, Seth Low, Andrew J. Montague, William W. Morrow, Wm. Barclay Parsons, Henry S. Pritchett, Elihu Root, Martin A. Ryerson, Charles D. Walcott, Henry P. Walcott, William H. Welch, Andrew D. White, Henry White, George W. Wickersham, Robert S. Woodward.

The minutes of the twelfth meeting were approved as printed and submitted to members of the Board of Trustees.

The reports of the President, the Executive Committee, the auditor, the Finance Committee, the Auditing Committee, directors of departments, and grantees of the Institution were presented and considered.

The following appropriations for the year 1915 were authorized:

Administration	$50,000
Publication	60,000
Division of Publications	10,000
Departments of Research	692,312
Minor Grants	109,300
Index Medicus	13,500
Insurance Fund	25,000
Reserve Fund	250,000
	1,210,112

The resignation of Dr. Simon Flexner was presented and accepted with regret.

Vacancies in the Board were reported, caused by the death of Dr. S. Weir Mitchell, by the death of Mr. John L. Cadwalader, by the resignation of Mr. Lyman J. Gage, and by the resignation of Dr. Simon Flexner. Balloting to fill the vacancies resulted in the election of the following persons to membership in the Board:

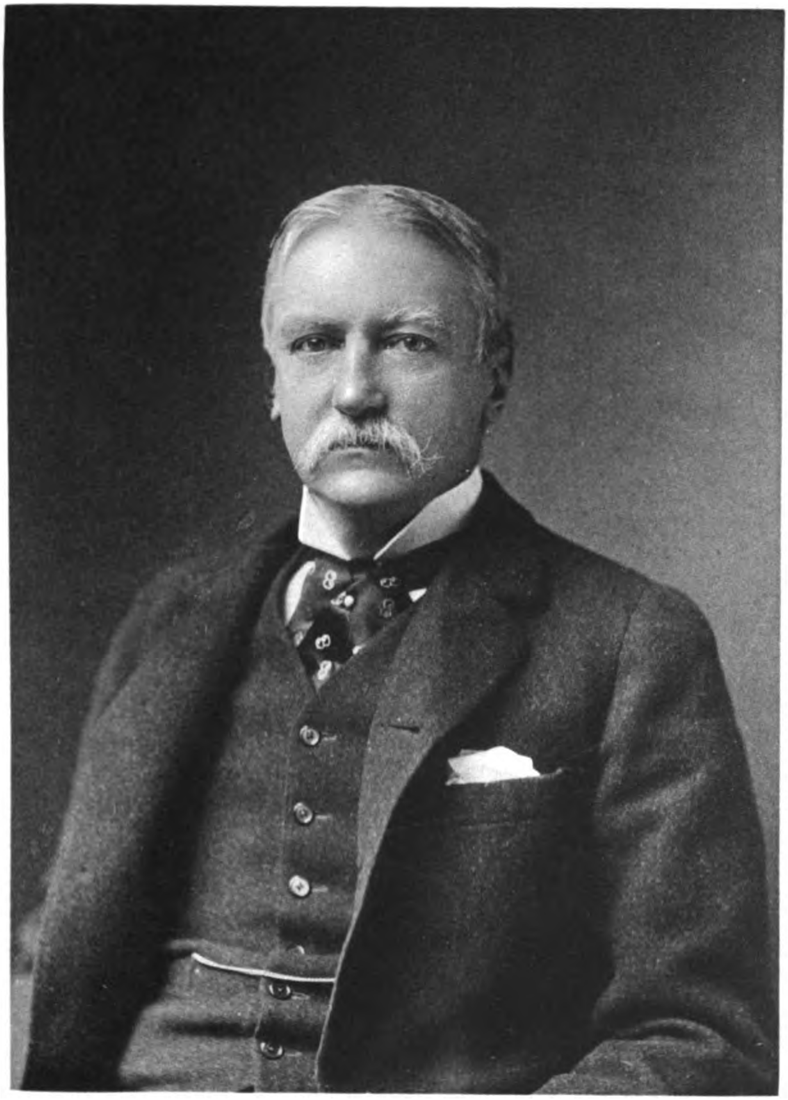
Mr. Charles Payne Fenner, of Louisiana.
Mr. Henry Cabot Lodge, of Massachusetts.
Mr. George Wharton Pepper, of Pennsylvania.
Dr. Theobald Smith, of New Jersey.

Mr. Henry White and Dr. Henry S. Pritchett were elected members of the Executive Committee to fill vacancies caused respectively by the resignation of Dr. Flexner and by the death of Dr. Mitchell. Mr. C. D. Walcott was reelected as a member of the Committee for a term of three years. Mr. Low and Dr. Pritchett resigned as members of the Finance Committee, Mr. Dodge and Mr. Wickersham being elected to fill vacancies caused thereby.

A Department of Embryology was formally established under the auspices of the Institution, Dr. Franklin P. Mall being appointed Director.

The Board adjourned at 1 p. m.

PLATE 2



JOHN LAMBERT CADWALADER
1837-1914

REPORT OF THE PRESIDENT

OF THE

CARNEGIE INSTITUTION OF WASHINGTON

FOR THE YEAR ENDING OCTOBER 31, 1914.

REPORT OF THE PRESIDENT
OF THE
CARNEGIE INSTITUTION OF WASHINGTON.

In conformity with Article IV, section 2, of the By-Laws of the Carnegie Institution of Washington, I have the honor to submit the following report on the work of the Institution for the fiscal year ending October 31, 1914, along with recommendations of appropriations for the ensuing year and with sundry suggestions concerning other matters of general or special interest.

This report is the thirteenth annual report of the Institution and is presented under the following principal heads:

1. Salient events of the year.
2. Researches of Institution.
3. Financial records.
4. Publications.
5. Proposals for budget for 1915 and other recommendations.

SALIENT EVENTS OF THE YEAR.

In my report of a year ago attention was called to the lengthy list of deceased members of the Board of Trustees of the Institution since its establishment in 1902. This list cited the names of thirteen men, all of whom had been members of the initial Board or of the Board as reorganized under the act of Congress of April 28, 1904. Along with this total of thirteen, must now be recorded the names of two other colleagues who were also members of the initial Board. These are Silas Weir Mitchell, who died at his home in Philadelphia, January 5, 1914; and John Lambert Cadwalader, who died at his home in the City of New York, March 11, 1914.

Necrology.

A singular series of circumstances is recalled by the deaths of these colleagues so soon after the death of John Shaw Billings, whose obituary was recorded in the preceding report. These three men, in many respects of widely different temperaments,

were long the most intimate of friends, were long closely associated in altruistic enterprises, and their careers were all terminated by death within an interval of twelve months to a day. The association of Billings and Mitchell arose during the stormy period of the Civil War and continued uninterruptedly for more than half a century; Mitchell and Cadwalader were brothers-in-law, Mitchell having married Cadwalader's sister, Mary, in 1875; Billings and Cadwalader collaborated actively for nearly a quarter of a century in the development of the public library system of New York City; while all three of these men were equally closely associated in the development of the Carnegie Institution of Washington. To have witnessed the united devotion of these men to the interests of the Institution and to other similar interests and to have been cognizant of their mutual personal attachments are rare experiences.

Dr. Mitchell was one of the best known and highly esteemed of Americans at home and abroad. He was at once a man of science and a man of letters. He is distinguished alike for his contributions to physiology and pathology and for his contributions to prose and poetry. His breadth of interest and his versatility as a writer have been rarely equalled. He was a member of the Executive Committee of the Institution from the time of its foundation to the time of his death, and although seventy-three years of age when he assumed the duties of this position he was continuously active, energetic, and helpful in the work of that body. His peculiar suggestiveness in research and the wide range of his personal studies are well illustrated by the fact that for an hour before the last meeting of the Executive Committee he attended (December 11, 1913) he discussed with me questions as widely different as the physics of the diffusion of odors, the literary value of the Institution's edition of the Arthurian Romances, and the possibility of discovering the characteristics of his own mental processes.

In the deliberations of the Trustees and of the Executive Committee Dr. Mitchell was a man of few words. He was somewhat handicapped by partial deafness, and he was rarely much

concerned with the details of fiscal business. With respect to the latter, indeed, he once remarked humorously to his colleagues that he had never understood, and that he never expected to understand, a formal financial statement. He was at his best as a correspondent and in informal conference. As a physician and as a humanist he had mastered the art of friendly counsel in other fields than those of pathology, in which he so long occupied a position of preeminence. He was wont to disclaim competence as a judge of men and their motives; it was his opinion that he could more accurately interpret the minds of women; but experience with him proved that he was an uncommonly capable adviser with respect to all affairs peculiarly humanistic, of which the Institution has naturally encountered a considerable share.

Socially, Dr. Mitchell was one of the most noteworthy personages in his native "Red City." His home, on Walnut Street, was an intellectual center about which clustered and from which radiated the best traditions of American manners and customs, so clearly delineated in his singularly elevated historical romances. Here he and his wife, who survived him by a few days only, were long graceful hosts to guests from near and far; here and at Bar Harbor, Maine, his summer home, were wrought out his numerous contributions to literature and to science which have long delighted and instructed his readers; and here he continued his activities in full possession of his faculties closely to the end of his life, whose span was only a month and a half short of eighty-five years.

The services rendered by Mr. Cadwalader to the Institution were quite different in kind from those rendered by his intimate coadjutors Billings and Mitchell. His services were, indeed, of a more fundamental character. He was legal counsel for the Institution; he drew up its constitution and by-laws; and his advice was always readily available in assisting the Institution to secure a systematic and rational development. Naturally enough, a novel establishment in whose origin and evolution there has been an unprecedented popular interest, leading neces-

sarily to an excess of expectations vastly greater than could be realized, has had not only to keep free from numerous untoward alliances but also to avoid numerous legal complications. In this branch of the Institution's work the conserving wisdom of Mr. Cadwalader has been invaluable. His readiness of comprehension of the essentials of a question and the clearness and justness of his recommendations made him a model counsellor for a research establishment. Impatient with pretense and with circumlocution, he got quickly at the gist of any problems submitted to him and he arrived equally quickly at practicable and honorable solutions for them.

One of the most noteworthy features of the advancing civilization of our times is seen in the increasing numbers of men and women willing to devote their fortunes, their superior learning, or their gratuitous labors in the promotion of undertakings for the common weal. In this sort of activity Mr. Cadwalader was a conspicuous figure; and no one could have given more freely of his time and talents than he. His aid to the Institution was a constant source of encouragement. It was occasionally essential to appeal to his knowledge of human nature as well as frequently essential to draw on his knowledge of legal affairs. Busily occupied as he was with professional engagements, he was ever ready to suspend them in order to aid the Institution. Even during his last illness, less than a month before his death, he insisted that he would gladly give me counsel at his bedside concerning a matter of pressing importance that had just then arisen. His fidelity to the Institution, extending thus near to the end of his life, was one of many manifestations of a fine idealism to which he often gave expression in conversation and in correspondence, to the effect that the Founder and the Trustees had entered into a copartnership whose unwritten obligations must be strictly observed.

It is fitting to record here also the death of an associate of the Institution distinguished for preeminence in the domain of celestial mechanics, namely, George William Hill, who died at his home in West Nyack, New York, April 16, 1914.* Dr. Hill's

*Hill was born in New York City on March 3, 1838. A more extended account of his life and work has been published in the Astronomical Journal, No. 668, June 5, 1914.

association with the Institution arose through the publication of his "Collected Works" (Publication No. 9, 1905–1907) in four quarto volumes, having an aggregate of 1,770 pages. His career in research was extraordinarily fruitful, extending with but few and brief interruptions for fifty-five years from the time of attainment of a baccalaureate degree at Rutgers College, in 1859, at the age of twenty-one years. His contributions to mathematico-physical astronomy are held to be the most important of any individual investigator of the nineteenth century after the epoch of Laplace. His researches relate to nearly every branch of celestial mechanics, ranging from the figure of the earth up to the most difficult problems presented by the solar system. He is best known, however, for his theories of planetary motions and for his theory of the moon. This latter alone, according to his eminent contemporary Poincaré, has rendered Hill's name immortal in the annals of astronomy.

Investigators of such high rank are in general little known and hence little appreciated by their contemporaries. Those who are extending the boundaries of knowledge are of necessity often in intellectual isolation. The advances they accomplish are less for themselves than for mankind. Adequate recognition of their labors is possible only from their successors. Hill understood well, and accepted without protest, these conditions of his chosen occupation. He asked only for opportunity to investigate unceasingly. The publication of his "Collected Works" by the Institution was an unexpected honor he esteemed very highly and an undertaking to which he gave characteristic attention, extending and completing for this purpose several unpublished memoirs. It would seem also that this recognition prompted him to further productivity, for since 1907 he has published a sufficient number of researches to make an additional volume for the series already issued by the Institution.

The Colburn Bequest.

Under the terms of the will of Mr. Richard T. Colburn, a resident of New York City, who died December 9, 1913, the American Association for the Advancement of Science and the Carnegie Institution of Washington are designated as residuary legatees of his estate, the proceeds of

which are to be shared equally by these two corporations. The design of Mr. Colburn in making this bequest is stated in his own words thus: "the intent in both cases being to have the revenue applied currently to original research in the physical or psychic demonstrable sciences." In accordance with advice expressed by him in his will, that the administration of his estate be committed to a reputable trust company, the surrogate court having jurisdiction has appointed the United States Trust Company of New York to act in this capacity.

While Mr. Colburn was primarily a man of affairs, interested in many business enterprises, he was also a reflective student of science and of contemporary social progress. He was a life member of the American Association for the Advancement of Science, and it was in connection with the annual meetings of this Association that my acquaintance with him began about fifteen years ago. He was interested especially in the economic and sociological aspects of anthropology. He was a well-read layman in the modern doctrine of evolution and an optimist with regard to the possibilities for human advancement which may come from a more general recognition of the principles and the methods of science. It was this optimism, doubtless, along with his appreciation of those principles and methods, that led him to leave, without solicitation, the bulk of his estate for the promotion of research.

Rise of other Research Establishments.

Progress toward stabler relations between the Institution and other organizations, to which reference was made in the two preceding reports, continues to be a noteworthy daily experience. The numerous fallacies hitherto prevalent with regard to the realizable functions of a research establishment and the extravagant illusions with respect to the capacities of the Institution's income are now slowly disappearing. Even in the popular mind the lines of demarcation which distinguish research from charity, education, and other worthy objects, are coming to be more widely recognized; while the arithmetical limitations of finite incomes, so commonly overlooked in altruistic enterprises, give promise of gradual restoration to their axiomatic integrity.

But more important indications of this progress are found in the improvement of existing organizations and in the development of new ones for the promotion of research, and in the aid it is now practicable to give them without endangering their sources of independent incomes and endowments. There is now manifest, indeed, a widely spread and rapidly increasing appreciation of the methods followed and of the results attained in systematic investigation, and this is leading to numerous well-defined efforts to secure definite knowledge and increased efficiency in nearly every department of contemporary activity. It may be safely predicted, therefore, that many independent organizations will enter the fields of research in the near future. The extensive, and probably unequalled, experience of the Institution, which is certain to be drawn upon heavily in this movement, should be readily available, therefore, for use by our prospective allies. Their entrance into these fields should be warmly welcomed. No greater good fortune could come to the Institution, for example, than a division of labors with a number of similarly well-founded establishments; and no greater good to society can arise than from a wider distribution of the duties and the responsibilities of research. Obviously important advantages to individual establishments must come from a broader dissemination of the vast aggregate of fruitless work now imposed upon them by those who claim the special privilege of ignoring alike the teachings of experience and the demonstrations of science.

In keeping with this attitude of welcome towards similar prospective organizations, it appears essential to add that with them, as with educational institutions, the only relations that can be stable and helpful are relations of reciprocity. These should be such especially as to secure the greatest freedom of interchange, among educational and research establishments, of eminent investigators. For, while institutions may continue indefinitely and thus have endless opportunities to add to the aggregates of learning, the life tenure of the individual is limited, and hence a full measure of usefulness to his race can not be rendered unless he is granted liberties corresponding to superior capacities.

There should be no fear that either class of these establishments will prove inimical to the other. The chief object and the common endeavor should be to secure for competent investigators the most favorable opportunities for productive research.

The international extent of the Institution's activities was as strikingly as unexpectedly demonstrated by the outbreak of the European war. In the early days of August representatives of the Institution were found to be scattered from Australia to Iceland, more than thirty of them being in or near to the war zone. With the nearly complete breakdown of international monetary exchange and with the difficulties of securing cash, even for the best of commercial paper, in foreign countries, general financial distress soon followed. Hence an urgent part of the business of the administrative office during the months of August and September consisted in providing for the immediate monetary needs of those representatives and for such further assistance as could be rendered in cases of detention or residence within the war zone. For relief in these unprecedented circumstances the Institution is chiefly indebted to the United States Government and to its numerous officials at home and abroad. Without the aid of the Departments of State and Treasury it would have been quite impracticable to secure such relief.

International Aspects of Institution's Work.

Happily, the losses to the Institution and to its associates resulting from the European war have thus far not been serious. It appears certain, however, that such losses must begin to accrue in the near future. The increased cost of materials, especially those used in laboratories, the increased cost of foreign exchange, of transportation, and of skilled labor, along with the diminishing purchasing capacity of the world's monetary standards, must all tend to decrease still further the effectiveness of the Institution's income. This effectiveness, it should be recalled, is now less than two-thirds of what it would be under such world conditions as obtained at the foundation of the Institution in 1902. The pending international conflict will require considerable changes also in the plans of some departments of the Institution, par-

ticularly those of Historical Research and Terrestrial Magnetism, while much work contemplated for prosecution in foreign countries must be delayed indefinitely if not abandoned.

But along with these international aspects of the Institution's work, which are not altogether free from disquieting elements, it seems fitting, at this time especially, to mention also, with grateful appreciation, the numerous courtesies and the cordial assistance rendered to investigators of the Institution by representatives of foreign countries. In a work embracing a wide variety of subjects and extending to nearly every country, it has been essential to solicit advice or aid from many diplomatic and consular officers and from many civil and military authorities. The response of these officials has been everywhere prompt and helpful, and in all of the varied experience with them there have arisen no misunderstandings and no untoward obstacles to the progress of research. This experience serves to emphasize the well-known but as yet quite inadequately utilized fact, that in the fields of tangible investigation, as illustrated especially by the older physical sciences, the disposition to submit questions in dispute to the arbitrament of demonstration is now well nigh spontaneous and universal. Should we not hope, therefore, that the domain of investigation and demonstration may be extended to include the more debatable fields of human interest and inquiry?

RESEARCHES OF INSTITUTION.

Some Lessons from Experience.

Nearly thirteen years have now elapsed since the foundation of the Institution in 1902. A majority of the larger departments of research established under the direct auspices of the Institution have been effectively at work for about a decade; while investigations of numerous individuals, primarily connected mostly with academic and other organizations, have been promoted for an approximately equal period of time. Thus, although this must be regarded as a very short interval in the career of an establishment whose history should be measured by centuries, it has been long enough to afford surprisingly large opportunities for the development of ideas and ideals concerning the conduct of research. In addition to the necessarily limited number of investigations actually undertaken by the Institution, it has entertained proposals for research in nearly every imaginable field of abstract thought and of applied knowledge. If under these circumstances the Institution has not learned something of the wisdom which is said to arise from experience, lack of abundance thereof can not be properly assigned as a reason for so obvious a lapse. An adequate account of this very extensive and very complex experience, which, while overloaded with the manifest and the impracticable, is yet rich in applicable instruction, may not be attempted here; an appropriate objective treatment would require a separate volume and another author. But it may be useful to contemporaries to set down here a few salient propositions, which, like those stated formally in my report for 1912, have been amply verified.

Thus, as regards research and the conditions favorable thereto, it is in evidence—

1. That it is inimical to progress to look upon research as akin to occultism and especially inimical to mistake able investigators for abnormal men. Successful research requires neither any peculiar conformity nor any peculiar deformity of mind. It requires, rather, peculiar normality and unusual patience and industry.

2. That fruitful research entails, in general, prolonged and arduous if not exhausting labor, for which all of the investi-

gator's time is none too much. Little productive work in this line may be expected from those who are absorbingly preoccupied with other affairs. Herein, as well as in other vocations, it is difficult to serve two or more exacting masters.

3. That those most likely to produce important results in research are those who have already proved capacity for effectiveness therein and who are at the same time able to devote the bulk of their energies thereto. In general, men are not qualified for the responsibilities of research until they have completed independently and published several worthy investigations.

4. That research, like architecture and engineering, is increasingly effective in proportion as it is carefully planned and executed in accordance with definite programs. A characteristic defect of a large majority of the proposals for research submitted to the Institution is a lack of tangible specifications. Estimates, especially of time and funds essential to carry out such proposals, are almost always too small. Those commonly made, even by skilled investigators, may be on the average safely doubled.

5. That, in spite of the most painstaking foresight, research tends to expand more rapidly and hence to demand a more rapid increase of resources than most other realms of endeavor. Its unexpected developments are often more important than its anticipated results and new lines of inquiry often become more urgent than those carefully prearranged for pursuit.

6. That it is much easier, in general, to do effective work of research in the older fields of inquiry than in the newer ones. It is especially difficult to enter those fields in which there is as yet no consensus of opinion concerning what may be investigated and what criteria may be followed. In some of the older fields, however, like the so-called humanities, for example, there is at present no such consensus of opinion, if one may judge from the large mass of expert but hopelessly conflicting testimony furnished to the Institution by its correspondents. In such fields it appears now practicable to proceed only in a somewhat arbitrary fashion, accomplishing here and there good pieces of work regardless of divided opinions or even in opposition to expert advice, in illustration of which may be cited the Institution's publications of the "Old Yellow Book" and the "Arthurian Romances."

The larger departments of research of the Institution are now so well established and so distinctive in their several fields that they might be regarded as so many separate organizations except for their dependence on the Institution for financial support. They are not uncommonly considered, in fact, as independent organizations, while several of them have been mistaken for the Institution as a whole. Such misapprehensions are inevitable, but their existence suggests a question well worthy of reflection, namely, whether it may not be well, in the course of time, for some, or all, of these departments to sever connections with the Institution if they should have the good fortune to receive adequate separate endowments. The only concern the Institution need have in such circumstances is that of securing to these departments the most favorable conditions for effective work. If this object may be best attained by independent foundations, or by affiliation with other organizations, no obstacle should be raised against such action.

Reports of Departments.

But quite apart from these hypothetical considerations, the existing relations of these departments to one another and to the Institution as a whole secure to them a degree of autonomy which could hardly be surpassed under other auspices. The liberties of action, thus designedly and freely conceded, imply corresponding responsibilities not only in departmental administration but also in departmental exposition, whether by summary annual reports or by elaborate monographs. Accordingly, and in conformity with other reasons referred to in previous reports, the following paragraphs aim to give brief indications only of departmental progress, reference being made for instructive details to the reports of the several directors in the current Year Book.

In connection with the subject of departmental researches particularly, the question is often asked "How can the 'practical results' attained be popularized and thus rendered available to the masses of mankind?" This is a question too large and too difficult for adequate discussion here, but it is one meriting studious contemplation in the interests of our successors. It may be recalled that a hopeful paragraph was devoted to this topic in my first annual report, of 1905, but subsequent experi-

ence does not seem to justify the optimism entertained at that time. [It is now plain, indeed, that while as a matter of fact truth is not only stranger but much more important than fiction, contemporary media for the dissemination of the sensational and the intangible are far more numerous and potent than the media for the dissemination of the demonstrable, and hence permanent, additions to knowledge. And it is equally plain that until there is an increased demand for less of the spectacular and for more of the real, both from journalists and from their readers, there can be little improvement in the popularization of discoveries and advances through such media. In the meantime, the increasing value of these researches, now everywhere recognized by scholars, may presently justify the engagement of an expert to popularize not simply the "practical results" but to furnish also what is in general more important, to wit, a clear and concise account of the principles and the methods by which such results are derived.]

Department of Botanical Research.

Although the greater part of the work of this department is carried on at its principal laboratory at Tucson, Arizona, it is essential to a comprehensive study of desert plant life to explore distant as well as adjacent arid regions. Thus, having published during the past year the results of an elaborate investigation of the region of the Salton Sea, the department is now, among many other activities, turning attention to similar desert basins, of which there are several in the Western States that have been studied hitherto in their geological rather than botanical aspects. These researches are entailing also many applications of the allied physical sciences not heretofore invoked to any marked extent in aid of botanical science. Hence there results properly a diversity of work quite beyond the implications of botany in the earlier, but now quite too narrow, sense of the word.

In addition to the work carried on by members of the departmental staff, various investigations have been pursued by about twenty collaborators, several of whom have been in temporary residence at the Desert Laboratory. Among the more noteworthy publications emanating from the department during the

year may be cited, along with the monograph on the Salton Sea referred to above, the instructive volume by Dr. Forrest Shreve, of the departmental staff, on "A Montane Rain-Forest" (Publication 199 of the Institution). Favorable progress has been made by Messrs. Britton and Rose, Research Associates of the department, in their elaborate investigation of the distribution and relationships of the Cactaceæ. The facilities of the Desert Laboratory have been enlarged during the year by the completion and equipment of a specially designed small building for studies in phyto-chemistry, which has been proved to play a highly significant rôle in desert life.

Department of Economics and Sociology.

The work of this department has been confined in recent years to the preparation of divisional monographs, as explained in previous reports. Dr. Victor S. Clark, in charge of the division of manufactures, has been able to devote his time exclusively to this work and has been furnished office quarters for this purpose in the Administration Building at Washington. Other heads of divisions have been able to give half or less time to their divisional work, which is thus progressing somewhat more favorably than hitherto. It is hoped, therefore, that some of the monographs under way may be ready for publication during the coming year. Of the comprehensive "Index of Economic Material in the Documents of the States" projected by the department and prepared under the direction of Miss A. R. Hasse, the volume for New Jersey is now in press. Volumes of this index for eleven different States have already been issued.

Department of Experimental Evolution.

The observational, statistical, and physical methods applied by this department are constantly adding to the sum of facts and of inductions essential to advances in biological knowledge. The range of application extends from the lowest organisms, like fungi, up to the highest, as typified in the race to which the investigators themselves belong. Thus, during the past year, observations and experiments have been made on mucors, plants, pigeons, poultry, and seeds, while the Director has continued his fruitful statistical

studies in the relatively new field of departures from normality in mankind. The variety of agencies employed in this wide range of inquiry now includes a permanent staff of about twenty members and a physical equipment enlarged during the year by the completion of an additional laboratory and a power-house. Early in the year the facilities of the department were increased by the successful transfer, from Chicago to Cold Spring Harbor, of the remarkable collection of pedigreed pigeons recently acquired by the Institution from the estate of Professor C. O. Whitman.

Among the numerous researches of the year to which attention is given in the departmental report, there may be cited, as of special interest, those of the Director in human heredity, those of Dr. Blakeslee and Dr. Gortner on mucors, those of Dr. Riddle on the Whitman pigeons, those of Dr. Harris on the characteristics of seeds, and those in cytology by Mr. Metz. It is of particular interest to note that, in all of these, definite, measurable relations are anticipated as attainable, just as such relations are now assumed to be attainable in the older physical sciences. The Director accepted an invitation from the New Zealand Government and from the British Association for the Advancement of Science to take part in a series of scientific conferences held in Australasia during the past summer. Dr. Shull, of the departmental staff, spent the year in Berlin preparing his account of the horticultural work of Luther Burbank. The department expresses regret at the loss from its staff of Dr. R. A. Gortner, who has resigned to accept a position in the University of Minnesota. His abilities as an investigator and his capacity for effective cooperation won high regard from his colleagues.

Geophysical Laboratory.

An instructive example of the favorable progress, which may be confidently expected in any field of research when entered by an adequately manned and equipped department devoted solely thereto, is afforded by the experience of the Geophysical Laboratory. In less than a decade this establishment has not only accomplished the formidable task of constructing the necessary apparatus and of preparing many

of the pure minerals concerned, but has already begun the processes of analysis and synthesis which are leading to extensive additions to our knowledge of rock and mineral formations found in the earth's crust. In illustration of these processes the Director's report cites the mineral system dependent on the elements lime, alumina, and silica, which elements include in their multifarious possible combinations the well-known but hitherto little understood compound called portland cement, whose properties have been determined as an incident to the general problem presented by this system.

Among the numerous problems under investigation at the Laboratory, one of immediate economic as well as of great theoretical interest may be cited here by reason especially of the fact that funds for its execution have been supplied by industrial sources; this is the problem of the "secondary enrichment of copper ores," and the success attained in its treatment demonstrates the practicability of advantageous cooperation between the Laboratory and industrial organizations without restriction to scientific procedure and publicity. The section of the Director's report devoted to this subject should be of special interest to geologists and to mining engineers as well as to copper-mining industries. A more comprehensive idea of the productive activities of the Laboratory may be gained by a glance at the section of the Director's report in which he gives brief abstracts of the publications which have emanated from members of the staff during the year. These publications embrace forty-nine titles of papers which have appeared in current journals or are in press, many of them having been published in German as well as in English.

Department of Historical Research.

The investigations of the Department of Historical Research have proceeded effectively in accordance with the plans outlined by the Director in his reports published in previous Year Books. In addition to the members of the permanent staff, several collaborators have taken part in these investigations, which have required explorations of historical archives in England, Scotland, France, Spain, Holland,

Russia, and Switzerland. Departmental plans for pursuit of peaceful studies in foreign archives, however, have suffered a serious check in the onset of the European war, and much work well started, or approaching completion, must now await developments from the pending conflict.

Two bulky volumes of guides to the sources of American history have issued from the department during the year as Publications 90A and 90B of the Institution. These are, respectively, "Guide to the Materials for American History to 1783, in the Public Record Office of Great Britain," and "Guide to the Materials in London Archives for the History of the United States since 1783." It had been anticipated that a similar guide to the data on American history in the archives and libraries of Paris, in preparation under the charge of Mr. Leland of the departmental staff, would be completed before the end of the present calendar year; but the exigencies of the war have required the suspension of this work at Paris and the return of Mr. Leland to the departmental office in Washington. Similarly, work undertaken for the department in Holland by Professor William I. Hull and in Spain by Mr. Francis S. Philbrick had to be suspended. On the other hand, researches under way in Great Britain and in Russia have suffered little interruption. Work at the home office has proceeded without discontinuity. The Director calls attention particularly to progress made in work on the projected "Atlas of the Historical Geography of the United States." Two divisions of this atlas, illustrating respectively the history of presidential elections and the records of votes cast in the House of Representatives for or against certain typical measures of legislation, extending from 1789 to 1914, are already well advanced.

Department of Marine Biology.

In accordance with plans recommended by the Director of the Department of Marine Biology and approved by the Trustees in 1912, an expedition to Torres Straits, Australia, a region already known to be remarkable for abundance and variety of marine life, was undertaken in the latter part of the preceding fiscal year. Early in September

1913, the Director and six collaborators arrived at Thursday Island in the Straits, expecting to use this relatively accessible island as a base of explorations; but it was soon found advantageous to locate on Maër Island, one of the Murray group, about 120 miles east-northeast, and near to the outer limit of Great Barrier Reef. Here a temporary laboratory was set up in the local courthouse and jail, generously placed at Dr. Mayer's disposal by the British authorities. The region proved to be one rich in coral reefs and in marine fauna for the work contemplated. Observations and experiments securing gratifying results were carried out during the spring months (in the southern hemisphere) of September and October 1913. In addition to the critical data secured by Dr. Mayer with respect to the corals about Maër Island, for comparison especially with corresponding data from the corals of Florida waters, observations and materials for important contributions to zoology were collected by each of his collaborators. One report, by Dr. H. L. Clark, is now in process of publication and is remarkable for the new species of echinoderms described and for the admirable drawings of these forms made from life by Mr. E. M. Grosse, of Sydney, Australia, who accompanied the expedition.

On returning to America from the southern hemisphere, the Director was engaged, during April and May, in two minor expeditions with the departmental vessel *Anton Dohrn*. The first of these was in aid of the researches of Dr. Paul Bartsch, on cerions, and required a cruise along the Florida Keys from Miami to Tortugas and return. The second expedition was in aid especially of Dr. T. W. Vaughan, long associated with the department in studies of corals and related deposits, and required a cruise from Miami, Florida, to the Bahamas and return. On June 9, 1914, work was resumed at the Tortugas Laboratory and continued until July 30. In all, fifteen collaborators during the year have availed themselves of the facilities afforded by the department. Brief accounts of their varied researches may be found in the Director's report in the current Year Book, while detailed accounts may be expected in due time in the departmental contributions.

Attention is invited to an interesting section of the Director's report devoted to a summary of the work accomplished by the department during the first decade of its existence. This section is instructive in showing that a decade is the smallest convenient unit of time for adequate estimation of the activities of such an establishment. It appears that during this decade 49 investigators have made use of the Tortugas Laboratory, 28 of these having returned two or more times, making a total of 108 visits to this relatively inaccessible center of research. Of the publications emanating from the department, 60 have been published by the Institution, while upwards of 40 have been published under other auspices; the Institution has issued 2,551 printed pages and 269 plates exclusive of annual reports appearing in the Year Books.

Department of Meridian Astrometry.

The activities of the Department of Meridian Astrometry are concentrated on the derivation of stellar positions for the comprehensive catalogue in preparation, on supplementary measurements of stellar coordinates with the meridian circle of the Dudley Observatory, and on investigations of residual stellar motions. The latter have now become the most important element in the definition of stellar positions by reason of the extraordinary recent progress in sidereal astronomy, to which the Department has contributed in large degree. Thus, along with the formidable computations required by the large mass of observations made by the Department at San Luis, Argentina, researches are simultaneously continued on the problems of star-drift, including the speed and direction of motion of our solar system. In the meantime, the catalogue is progressing favorably and some portions of the observatory list of miscellaneous stars are approaching completion, although cloudiness during the past two winters has interfered with this part of the departmental program. In the meantime, also, the manuscript of the zone catalogue of stars whose positions were measured at the observatory during the years 1896 to 1900 is undergoing the final process of comparison and checking preparatory to publication.

The anticipations of a specially favorable environment, which were entertained when the Nutrition Laboratory was located in Boston near the Harvard Medical School and near several existing and projected hospitals, are now fully realized; and it would appear that the Laboratory is reciprocally advantageous to the several establishments with which it is in immediate contact. Indeed, with this, as with all other departments of research founded by the Institution, the only fears to be seriously entertained are those due to increasing capacity for usefulness and scientific progress, since such capacity tends quite properly to grow faster than the Institution's income warrants.

The Nutrition Laboratory.

The completion of adjacent buildings and streets has permitted bringing the grounds of the Laboratory into harmony with its physical surroundings. Improvements have been made in the Laboratory itself and several additions to equipment have been installed. These latter include new respiration apparatus for studies of metabolism in muscular work of men and of small animals, a reconstruction of an earlier form of bed calorimeter, and additional apparatus for photo-electric registration of physiological action in subjects under observation, whether near by or at a distance.

As indicated in previous reports, the Laboratory and its work are subjects of international as well as national interest and many cooperative efforts are arising therefrom. Thus, Dr. Hans Murschhauser, of the Kinderklinik in Düsseldorf, and Dr. Carl Tigerstedt, of Helsingfors, have each spent several months at the Laboratory during the year as Research Associates; while M. Lucien Bull, Assistant Director of the Institut Marey, in Paris, spent several weeks at the Laboratory studying its apparatus and methods. The researches in progress by the Laboratory staff are briefly summarized by the Director under twenty different heads in his annual report, to which reference must be made for personal and technical details. Abstracts are given also in his report of the publications issued during the year or now in press. Of these, attention may be called particularly to "The gaseous metabolism of infants with special reference to its relation to

pulse-rate and muscular activity," by Francis G. Benedict and Fritz B. Talbot (Publication No. 201) and to "A study of prolonged fasting," by Francis G. Benedict (in press as Publication No. 203).

Department of Terrestrial Magnetism.

The extensive operations of the Department of Terrestrial Magnetism on the oceans and in foreign countries have been adequately supplemented during the year by the new departmental laboratory, whose completion and occupation took place nearly simultaneously with the beginning of the second decade of the Department's existence. This laboratory and its site provide greatly enlarged facilities for research as well as unsurpassed quarters for the resident departmental staff. This site (of 7.4 acres) is well protected on all sides from possible objectionable elements, while the laboratory is an exceptionally well-lighted, fire-proof building with 44 rooms and many specially designed adjuncts. Attention may be invited particularly to the relatively low cost (22 cents per cubic foot) of this building, and to the reasons why it, like the Geophysical Laboratory and the Nutrition Laboratory, has been economically built. These reasons are found mainly in deliberate preparation of preliminary programs, in carefully drawn plans and specifications by competent architects, and in responsible superintendence of construction.

Near the end of the preceding fiscal year the non-magnetic ship *Carnegie* returned to New York City, where she underwent such extensive repairs as are always required by wooden vessels after long cruises in tropical waters. After refitting, she left New York, June 8, 1914, for a cruise in the North Atlantic. In this, the third of her expeditions, she traversed about 10,600 miles, making a first stop at Hammerfest, Norway, July 3, reaching the high latitude 79° 52′ off the northwest coast of Spitzbergen, touching at Reykjavik, Iceland, August 24, and returning to the base station at Greenport, Long Island, October 9, and to Brooklyn, New York, October 21. During this cruise the *Carnegie* was in command of Mr. J. P. Ault. She is now refitting for a longer cruise during 1915–1916, in southern latitudes (50° to 75°), where magnetic observations require supplementing.

An attempt at an ocean expedition into Hudson Bay was made under the charge of Mr. W. J. Peters during the past summer, but on account of unusual obstacles from ice this proved only partly successful. Entrance into the Bay with the auxiliary schooner *George B. Cluett*, chartered for this purpose from the Grenfell Association, was blocked until September 2, leaving less than a month's time available for surveys.

Determinations of magnetic elements on land have been continued in six parts of Africa, in as many States of South America, and in Australia, bringing the surveys of all these continental areas to a well-advanced stage.

Attention may be called to an interesting summary given by the Director in his current report of work accomplished by the department during the past decade, as well as to accounts of the investigations now in progress under the department at its Laboratory, of the operations on land and sea, and of the departmental publications of the year. Of these latter, volume II of the "Researches of the Department of Terrestrial Magnetism," under the sub-title "Land magnetic observations, 1911 to 1913, and reports on special researches," by L. A. Bauer and J. A. Fleming, is now in press.

The Solar Observatory.

With the end of the current year the Mount Wilson Solar Observatory, like most other departments of the Institution, will have completed a first decade of its history. Quite appropriately, this establishment was founded at an epoch of maximum sun-spots, and a marked increase in solar activity during the past year furnishes similarly auspicious conditions for entrance into a second decade of research. But much more auspicious conditions are found in the extensive experience and in the effective equipment acquired along with the capital progress attained during this first decade. The most sanguine astronomer would have hesitated at the earlier epoch to predict that these latter conditions could be realized at the present epoch. Herein also is found a signal illustration of the superior effectiveness of establishments primarily designed for and exclusively devoted to research as compared with establishments in which research is a matter of secondary interest.

The work of the Observatory for the year is much too extensive to permit of adequate summary here. But this is unnecessary, since the Director's report, in addition to detailed accounts of observations, investigations, and construction, gives a condensed abstract of the salient results arrived at. These results are briefly and clearly stated in 59 paragraphs. They refer to correspondingly numerous measurements, calculations, and inductions made in studies of the sun and other stellar bodies whose characteristic properties are now stimulating extraordinary advances in cosmic physics.

Progress in construction of the 100-inch telescope has been made as rapidly as could be expected in so formidable an undertaking. The delicate optical task of shaping the 100-inch mirror has been brought successfully by Mr. Ritchey to the stage of sphericity which precedes the final state of parabolization. The difficulties due to distortion of the mass of the disk, referred to in previous reports, have been overcome and other obstacles due to temperature inequalities in the optical room are likewise yielding to appropriate precautions. In the meantime the foundations for this telescope have been completed and the mounting and dome are expected to be ready for erection during the coming year. Several smaller parts and accessories for this instrument, requiring special exactness, are under construction at the shops of the Observatory in Pasadena. Many additions and improvements in the apparatus already installed at the Observatory have been made. The 60-foot tower telescope particularly, which was originally cheaply constructed in order to test the possible advantages of such a departure from earlier forms of telescopes, has been put in a state of efficiency comparable with that of the 150-foot tower telescope, leaving the latter free for the uses to which it is specially devoted. In these general improvements much attention has been given to rendering the plant on Mount Wilson more nearly fire-proof. The mountain road has been repaired, widened, and strengthened in many parts in anticipation of the heavy traffic essential to transportation of the 100-inch telescope to its destination.

Work of Research Associates and Collaborators.

The variety and extent of the work carried on by Research Associates and collaborators has led to the widely spread but erroneous notion that the Institution has entered, or is able to enter, all possible fields of investigation, and that an expert can be supplied offhand for immediate consideration of any question which the world may submit. But while such comprehensive capacity is obviously unattainable by finite means, or by any single establishment, the scope and ramifications of this work are such as to defy adequate condensation and exposition within the limits of an administrative report. To understand this branch of the Institution's activities one must at least read the titles of the reports and the publications which appear in the current Year Book and know something of the contributing authors and their environments. Summarily it may be stated that more than a hundred individuals have been engaged in these activities during the past year and that their work embraces a range of about thirty different subjects of research. Although attempts to draw lines of distinction between adjacent fields of advancing knowledge are alike futile and inimical to progress, it may be of interest to note with respect to these subjects that if they be classified under the two categories of descriptive sciences and mathematico-physical sciences, respectively, they will be found to be about evenly divided. It may be noted also that in this work the so-called "humanities" represent no small share, since researches have been promoted during the past year in Roman archeology, in Central American archeology, in Roman paleography, in history, in law, in linguistics and in several branches of literature. But in all this latter work the object has been not to fix, nor to accept, categories, nor to determine "shares," but to produce results of permanent value.

Referring to the individual reports and to the bibliographic lists in the current Year Book for accounts of the investigations and of the publications of the year in this highly diversified branch of the Institution's work, it must suffice here to cite a few salient facts indicative of progress. Thus, Dr. Van Deman, in her studies of Roman archeology, has developed criteria for

determining epochs and periods in the evolution of Roman construction, and hence in the evolution of Roman history. In the allied field of Roman paleography Dr. Loew has published, through the Clarendon Press, Oxford, a volume of researches under the title, "The Beneventan Script; A History of the South Italian Minuscule." The extensive researches in embryology carried on under the direction of Professor Mall, with the collaboration of a number of associates, have proved highly productive, as shown by the publications issued and in press. Similarly, attention may be called to the fruitful studies of Dr. Osborne and Professor Mendel, which promise to throw important light on the intricate physico-chemical processes of animal nutrition and growth. The older sciences of chemistry and physics have made not less important progress through the contributions of a dozen associates and many more collaborators. A very noteworthy advance has been secured in meteorology by Professor Bjerknes through the international adoption of his methods and units for expressing meteorological data. Beginning with this calendar year and continuing up to the onset of the European war, the United States Weather Bureau issued daily weather maps of the whole northern hemisphere in conformity with these new methods and units, greatly to the advantage of theoretical and applied meteorology. The comprehensive and always highly suggestive expositions in geology and in cosmogony for which Professor Chamberlin has long been distinguished have stimulated his colleagues, Professors Michelson, Gale, and Moulton, to the production of a capital contribution to geophysics in an ingenious and conclusive proof that the rigidity of the earth is about the same as that of steel. And finally, in illustration of the ease of passage from one field to another in this complex miscellany of independent researches, there may be cited the concordances of the earlier poet Horace and the later poet Spenser, now in press as numbers 202 and 189, respectively, of the Institution's series of publications.

FINANCIAL RECORDS.

Financial Statement for Fiscal Year 1913-1914.

The sources of funds available for expenditure during the past fiscal year, the allotments for the year, the revertments made during the year, and the balances unallotted and unexpended at the end of the year are shown in detail in the following statement:

Object of appropriation.	Balances unallotted Oct. 31, 1913.	Appropriation Dec. 12, 1913.	Revertments Nov. 1, 1913, to Oct. 31, 1914.	Total.	Aggregates of allotments and amounts expended and transferred.	Balances unallotted Oct. 31, 1914.
Large grants	....	$746,545.00	$22,000.00	$768,545.00	$768,545.00	....
Minor grants	$5,262.56	134,285.89	2,300.06	141,848.51	136,685.00	$5,163.51
Publication	15,503.21	60,000.00	14,765.76	90,268.97	73,848.78	16,420.19
Administration	....	50,000.00	10,000.00	60,000.00	60,000.00	....
Reserve fund	....	250,000.00	....	250,000.00	250,000.00	....
Insurance fund	....	25,000.00	....	25,000.00	25,000.00	....
Total	20,765.77	1,265,830.89	49,065.82	1,335,662.48	1,314,078.78	21,583.70

Summary of Receipts and Expenditures of the Institution to date.

The aggregates of receipts from interest on endowment, from interest on bond investments, from interest on deposits in banks, from sales of publications, from refunds on grants, and from miscellaneous sources, for each year since the foundation of the Institution, are shown by the following table; the grand total of these to date is $10,441,486.21.

Aggregates of financial receipts.

Year ending Oct. 31.	Interest on endowment.	Interest on bonds and bank deposits.	Sales of publications.	Refund on grants.	Miscellaneous items.	Total.
1902	$250,000.00	$9.70	....	....	$1,825.52	$251,835.22
1903	500,000.00	5,867.10	$2,286.16	....	101.57	508,254.83
1904	500,000.00	33,004.26	2,436.07	$999.03	....	536,439.36
1905	500,000.00	25,698.59	3,038.95	200.94	150.00	529,088.48
1906	500,000.00	27,304.47	4,349.68	2,395.25	19.44	534,068.84
1907	500,000.00	22,934.05	6,026.10	2,708.56	15.22	531,683.93
1908	550,000.00	17,761.55	7,877.51	25.68	48,034.14	623,698.88
1909	600,000.00	14,707.67	11,182.07	2,351.48	103,564.92	731,806.14
1910	600,000.00	10,422.78	10,470.25	1,319.29	54,732.45	676,644.73
1911	975,000.00	14,517.63	10,892.26	4,236.87	923.16	1,005,569.97
1912	1,100,000.00	31,118.41	11,496.13	1,658.88	96,035.01	1,240,308.42
1913	1,103,355.00	46,315.60	12,208.66	3,227.53	345,769.95	1,510,876.74
1914	1,105,084.17	59,298.63	11,402.40	7,819.70	577,305.77	1,760,910.67
Total	8,783,439.17	308,960.44	93,666.24	26,943.21	*1,228,477.15	10,441,486.21

*Of this amount $1,215,500 came from the sale of bonds in 1908, 1909, 1910, 1912, 1913, 1914.

The purposes for which funds have been appropriated by the Board of Trustees of the Institution may be summarily classified under five heads: (1) investments in bonds; (2) large projects; (3) minor projects, special projects, and research associates and assistants; (4) publications; (5) administration. The following table shows the actual expenditures under these heads for each year since the foundation of the Institution:

Purposes for which funds have been appropriated.

Year ending Oct. 31.	Investments in bonds.	Large projects.	Minor projects, special projects, research associates, and assistants.	Publications.	Administration.	Total.
1902....	....	....	$4,500.00	....	$27,513.00	$32,013.00
1903....	$100,475.00	....	137,564.17	$938.53	43,627.66	282,605.36
1904....	196,159.72	$49,848.46	217,383.73	11,590.82	36,967.15	511,949.88
1905....	51,937.50	269,940.79	149,843.55	21,822.97	37,208.92	530,753.73
1906....	63,015.09	381,972.37	93,176.26	42,431.19	42,621.89	623,216.80
1907....	2,000.00	500,548.58	90,176.14	63,804.42	46,005.25	702,534.39
1908....	68,209.80	448,404.65	61,282.11	49,991.55	48,274.90	676,163.01
1909....	116,756.26	495,021.30	70,813.69	41,577.48	45,292.21	769,460.94
1910....	57,889.15	437,941.40	73,464.63	49,067.00	44,011.61	662,373.79
1911....	51,921.79	463,609.75	63,048.80	37,580.17	45,455.80	661,616.31
1912....	436,276.03	519,673.94	103,241.73	44,054.80	43,791.13	1,147,037.63
1913....	666,428.03	698,337.03	110,083.06	53,171.59	43,552.89	1,571,572.60
1914....	861,915.73	817,894.52	107,456.05	44,670.55	44,159.54	1,876,096.39
Total.	2,672,984.10	5,083,192.79	1,282,033.92	460,701.07	548,481.95	10,047,393.83

The following list shows the departments of investigation to which the larger grants were made by the Trustees at their last annual meeting and the amounts allotted from these grants by the Executive Committee during the year:

Department of Botanical Research........................	$42,140.00
Department of Economics and Sociology....................	5,000.00
Department of Experimental Evolution.....................	63,479.00
Geophysical Laboratory..................................	85,500.00
Department of Historical Research.........................	31,100.00
Department of Marine Biology.............................	19,150.00
Department of Meridian Astrometry........................	25,180.00
Nutrition Laboratory....................................	45,798.00
Division of Publications (office expenses)..................	10,000.00
Solar Observatory.......................................	220,892.00
Department of Terrestrial Magnetism.......................	157,406.00
Researches in Embryology................................	26,900.00
Total..	732,545.00

The following statements show the fields of investigation to which minor grants were assigned, together with the names of the grantees and the amounts of the grants; also the grants for publications authorized during the year; and the sources and amounts of revertments from November 1, 1913, to October 31, 1914.

Details of minor grants.

Fields of investigation.	Names of grantees.	Amounts of grants.
Astronomy	Kapteyn, J. C	$2,000.00
Archeology	Van Deman, E. B	1,800.00
Bibliography	Index Medicus	12,500.00
Biology	Minot, C. S	2,000.00
	Watson, J. B	500.00
	Vaughan, T. W	700.00
Botany	Britton, N. L., and J. N. Rose	8,000.00
	Clements, F. E	1,500.00
Chemistry	Acree, S. F	2,000.00
	Baxter, G. P	1,500.00
	Jones, H. C	2,200.00
	Morse, H. N	4,000.00
	Noyes, A. A	3,000.00
	Richards, T. W	3,000.00
	Sherman, H. C	1,200.00
	Remsen, Ira	1,500.00
Geology	Chamberlin, T. C	4,000.00
	Moulton, F. R	2,000.00
History	Bandelier, Adolf F	2,000.00
	Osgood, H. L	2,000.00
	Mahan, Alfred T	2,400.00
Literature	Bergen, Henry	1,800.00
Mathematics	Morley, Frank	1,200.00
Meteorology	Bjerknes, V	1,800.00
Nutrition	Murschhauser, Hans	1,000.00
	Osborne, T. B., and L. B. Mendel	15,000.00
Paleontology	Case, E. C	660.00
	Hay, O. P	3,000.00
	Wieland, G. R	3,000.00
Paleography	Loew, E. A	1,800.00
Physics	Hayford, J. F	2,000.00
	Nichols, E. L	3,000.00
	Nipher, F. E	500.00
	Barus, Carl	500.00
	Howe, H. M	500.00
Physiology	Cooke, Elisabeth	600.00
	Reichert, E. T	3,000.00
Zoology	Castle, W. E	2,500.00
	Naples Zoological Station	1,000.00
Brown, Herbert D., consulting actuary		1,200.00
Exhibit at Panama-Pacific International Exposition		10,000.00
Model of the *Carnegie*		1,250.00
Administration Building (additions)		575.00
		115,685.00

Grants for publications authorized during the year.

Barus, Carl	$800.00
Bauer, L. A., and J. A. Fleming	2,400.00
Benedict, F. G., and F. B. Talbot	1,800.00
Benedict, F. G	2,400.00
Bolton, H. E	467.87
Case, E. C	2,000.00
Clark, E. R., J. C. Watt, and A. W. Meyer	1,150.00
Clark, H. L	8,000.00
Cooper, Lane	2,500.00
Davenport, C. B	229.38
Detlefsen, J. A	1,700.00
Hedrick, H. B	1,500.00
Jones, H. C., et al	1,400.00
Livingston, B. E., et al	450.00
Mall, F. P	2,200.00
Mayer, A. G	400.00
Morse, H. N	1,600.00
Ptolemy's Almagest	500.00
Rivers, W. H. R., A. E. Jenks, and S. G. Morley	951.53
Shreve, Forrest	1,400.00
	33,848.78

Sources and amounts of revertments from Nov. 1, 1913, to Oct. 31, 1914.

Large grants:		
Transferred from minor grants	$6,000.00	
Revertment, Division of Publications	1,000.00	
Revertment, Department of Meridian Astrometry	5,000.00	
Revertment, Research in Embryology	10,000.00	
		$22,000.00
Minor grants:		
Bandelier, A. F., Grants Nos. 832, 906	2,000.06	
Tigerstedt, Carl, Grant No. 892	300.00	
		2,300.06
Publications		
Andrew, C. M., Grant No. 875	355.01	
Barnard, E. E., Grant No. 455	4,700.00	
Barus, Carl, Grant No 946	158.47	
Benedict, F. G., and E. P. Cathcart, Grant No. 883	741.04	
Benedict, F. G., and Frits B. Talbot, Grant No. 947	885.38	
Case, E. C., S. W. Williston, and M. G. Mehl, Grant No. 871	171.05	
Castle, W. E., and C. C. Little, Grant No. 823	771.34	
Castle, W. E., and John C. Phillips, Grant No. 894	200.36	
Finley, J. P., and William Churchill, Grant No. 882	723.93	
Huntington, Ellsworth, Grant No. 887	487.75	
Jones, H. C., Grant No. 870	217.80	
Jones, H. C., Grant No. 876	367.82	
Lehmer, D. N., Grant No. 732	174.34	
Lehmer, D. N., Grant No. 807	65.39	
MacDougal, D. T., et al, Grant No. 890	743.19	
MacDowell, E. C., and W. E. Castle, Grant No. 895	285.55	
Morse, H. N., Grant No. 899	317.62	
Parker, D. W., Grant No. 815	83.21	
Paullin, C. O., and F. L. Paxson, Grant No. 805	603.98	
Shreve, Edith B., Grant No. 891	264.54	
Shreve, Forrest, Grant No. 929	517.68	
Smith, Edwin F., Grant No. 825	396.20	
Sommer, H. Oskar, Grant No. 391	1,140.18	
Weed, L. H., Grant No. 886	59.95	
Wright, A. H. Grant No. 893	333.98	
		14,765.76
Administration:		
Revertment from allotted balance		10,000.00
		49,065.82

Investments in Property. On account of site for and construction of the Administration Building of the Institution, and on account of real estate, buildings, and equipments of departmental establishments, the following sums have been expended:

Schedule of real estate, equipments, and publications.

Administration:		
Building, site, and equipment		$331,980.61
Publications:		
Stock on hand (Oct. 31, 1914)	$229,564.20	
Outstanding accounts (Oct. 31, 1914)	2,703.26	
		232,267.46
Department of Botanical Research (Sept. 30, 1914):		
Buildings, office, and operating	45,782.37	
Laboratory equipment	9,431.43	
		55,213.80
Department of Experimental Evolution (Sept. 30, 1914):		
Buildings, office, and library	101,547.42	
Laboratory apparatus	6,767.24	
Operating appliances and grounds	18,397.01	
		126,711.67
Geophysical Laboratory (Sept. 30, 1914):		
Building, library, operating appliances	119,296.87	
Laboratory apparatus	71,947.70	
Shop equipment	15,019.66	
		206,264.23
Department of Historical Research (Sept. 30, 1914):		
Office	1,706.15	
Library	2,723.14	
		4,429.29
Department of Marine Biology (Sept. 30, 1914):		
Vessels	32,325.40	
Buildings, docks, furniture, and library	11,328.56	
Apparatus and instruments	4,728.38	
		48,382.34
Department of Meridian Astrometry (April 30, 1914):		
Apparatus and instruments		2,394.34
Nutrition Laboratory (Sept. 30, 1914):		
Building, office, and shop	116,493.69	
Laboratory apparatus	18,965.26	
		135,458.95
Solar Observatory (Aug. 31, 1914):		
Buildings, grounds, road, and telephone line	195,557.11	
Shop equipment	36,134.35	
Instruments	378,247.36	
Furniture and operative appliances	81,380.20	
Hooker 100-inch reflector	183,929.77	
		875,248.79
Department of Terrestrial Magnetism (Sept. 30, 1914):		
Building, site, and office	126,507.28	
Vessel and survey equipment	121,237.73	
Instruments, laboratory, and shop equipment	49,896.12	
		297,641.13
		2,315,992.61

Expenses of Maintenance of Administration Building. The cost of maintenance of the Administration Building, including the items of fuel, lighting, janitorial services, maintenance of grounds, repairs, and other incidental expenses, has been, for 1910, $2,981.65; for 1911, $2,641.53; for 1912, $2,919.89; for 1913, $2,601.15, and for 1914, $3,251.08.

The improvements in the Assembly Room and the repairs to the roof of the coal vault, as described in detail in the President's report for last year, have been completed at a total cost (including purchase and installation of a motor generator and auxiliary apparatus) of $10,035.16. In addition, the Executive Committee has authorized, during the past year, the installation of 40 additional feet of double-faced steel bookshelving for housing the publications of the Institution and 40 steel bins for the storage of printing paper in the basement of the Administration Building. This equipment has been satisfactorily built and installed at a cost of $575.

Additions, Repairs, and Improvements to Administration Building.

During the year the wooden floors in the basement of the building have been removed, and in turn replaced by floors of cement. Wooden window-frames, baseboards, and sash, which might prove a harboring place for termites, that threatened to seriously damage these rooms, have also been replaced by corresponding parts of steel. The total cost of these improvements, not yet paid for, will be about $2,500, the allotted amount, as stated in the President's report of last year.

PUBLICATIONS.

The publication of twenty volumes has been authorized by the Executive Committee during the year, at an aggregate estimated cost of $33,848.78. The following list gives the titles and names of the authors of the publications issued during the year; it includes 23 volumes, with an aggregate of 4,978 octavo pages and 1,934 quarto pages. Twenty-nine additional volumes are now in press.

Publications Authorized and Issued during the Year.

List of Publications Issued during the Year.

Year Book, No. 12, 1913. Octavo, xvi+336 pages, 13 plates.
Index Medicus, Second Series, vol. II, 1913. Octavo, 1,681 pages.
No. 27. Smith, Erwin F. Bacteria in Relation to Plant Diseases. Quarto. Vol. III. Vascular Diseases. viii+281 pages, 46 plates, 138 text figures.
No. 90A. Andrews, Charles M. Guide to the Materials for American History, to 1783, in the Public Record Office of Great Britain. Vol. II. Departmental and Miscellaneous Papers. Octavo, viii+427 pages.
No. 90B. Paullin, C. O., and F. L. Paxson. Guide to the Materials in London Archives for United States History since 1783. Octavo, xi+642 pages.
No. 149. Barus, Carl. The Production of Elliptic Interferences in Relation to Interferometry. Part III. Octavo, pages vi+169–273, text figures 65–119.
No. 165. Lehmer, Derrick N. Tables giving a Complete List of Prime Numbers between the limits 1 and 10,006,721. Folio, xvi+133 pages.
No. 182. Papers from the Tortugas Laboratory of the Carnegie Institution of Washington. Vol V. Octavo, iii+222 pages, 7 plates, 3 maps, 68 figures.
No. 183. Papers from the Tortugas Laboratory of the Carnegie Institution of Washington. Vol. VI. Octavo, iii+323 pages, 27 plates, 97 figures.

List of Publications Issued during the Year—Continued.

No. 184. Finley, J. P., and William Churchill. The Subanu: Studies of a Sub-Visayan Mountain Folk of Mindanao. Octavo, IV+236 pages, 2 plates.

No. 185. Hasse, Adelaide R. Index to United States Documents relating to Foreign Affairs, 1828–1861. Quarto. Part I, A–H. 793 pages.

No. 187. Benedict, Francis G., and E. P. Cathcart. Muscular Work: A Metabolic Study with Special Reference to the Efficiency of the Human Body as a Machine. Octavo, VII+176 pages, 1 plate, 10 figures.

No. 191. Weed, Lewis H. A Reconstruction of the Nuclear Masses in the Lower Portion of the Human Brain-Stem. Quarto, 78 pages, 6 plates.

No. 192. Huntington, Ellsworth, with contributions by Charles Schuchert, A. E. Douglass, and C. J. Kullmer. The Climatic Factor as Illustrated in Arid America. Quarto, 341 pages, 12 plates, 2 maps, 90 figures.

No. 193. MacDougal, D. T., and Collaborators. The Salton Sea: A Study of the Geography, the Geology, the Floristics, and the Ecology of a Desert Basin. Quarto, XI+182 pages, 32 plates, 4 figures.

No. 194. Shreve, Edith B. The Daily March of Transpiration in a Desert Perennial. Octavo, 64 pages, 1 plate, 27 text figures.

No. 195. Castle, W. E., and John C. Phillips. Piebald Rats and Selection: An Experimental Test of the Effectiveness of Selection and of the Theory of Gametic Purity in Mendelian Crosses. (Paper No. 21, Station for Experimental Evolution.) Octavo, 56 pages, 3 plates.

No. 196. MacDowell, E. C., and W. E. Castle. Size Inheritance in Rabbits. (Paper No. 22, Station for Experimental Evolution.) Octavo, 55 pages, 9 figures.

No. 197. Wright, Albert Hazen. Life Histories of North American Anura: The Anura of Ithaca, New York. Octavo, 98 pages, 21 plates.

No. 198. Morse, H. N. The Osmotic Pressure of Aqueous Solutions: Report on Investigations made in the Chemical Laboratory of the Johns Hopkins University during the years 1899–1913. Octavo, 222 pages, 5 plates, 49 text figures.

No. 199. Shreve, Forrest. A Montane Rain-forest: A Contribution to the Physiological Plant Geography of Jamaica. Octavo, 110 pages, 29 plates, 18 figures.

No. 200. W. H. R. Rivers, A. E. Jenks, and S. G. Morley. Reports upon the Present Condition and Future Needs of the Science of Anthropology. Quarto, 91 pages, 14 plates.

No. 201. Benedict, F. G., and Fritz B. Talbot. The Gaseous Metabolism of Infants with Special Reference to its Relation to Pulse-rate and Muscular Activity. Octavo, 168 pages, 65 figures.

Sales of Publications and Value of those on hand.

The following table shows the amounts received from subscriptions to the Index Medicus, from sales of Year Books, and from sales of all other publications for each year since the foundation of the Institution:

Table showing sales of publications.

Year.	Index Medicus.	Year Book.	Miscellaneous books.
1903........	$2,256.91	$29.25	....
1904........	2,370.47	52.85	$12.75
1905........	2,562.76	44.75	431.44
1906........	2,970.56	37.60	1,341.52
1907........	3,676.71	56.50	2,292.89
1908........	3,406.19	99.65	4,371.67
1909........	4,821.85	73.01	6,287.21
1910........	4,470.50	100.70	5,899.05
1911........	4,440.21	85.50	6,366.55
1912........	4,652.14	61.65	6,782.34
1913........	4,992.02	75.95	7,140.69
1914........	5,079.16	49.65	6,273.59
Total.......	45,699.48	767.06	47,199.70

At the end of the fiscal year just closed there are on hand 91,951 volumes of miscellaneous publications and Year Books, having a sale value of $214,791.45; also 29,481 numbers of the Index Medicus, having a sale value of $14,772.75. The total value of publications on hand is therefore $229,564.20.

In connection with the above statement it is fitting to add that since the foundation of the Institution there have been distributed, chiefly by gifts to libraries and to authors, but to a noteworthy extent also by sales, a total of 132,430 volumes of publications of the Institution.

Growth and Extent of Institution's Publications.

The data furnished in the following table are of statistical interest in respect to the work of publication of the Institution. Two hundred and seventy-six volumes, embracing a total of more than 73,000 pages of printed matter, have thus far been issued by the Institution.

Table showing number of volumes, number of pages (octavo and quarto), and totals of pages of publications issued by the Institution for each year and for the thirteen years from 1902 to 1914.

Year.	Number of volumes issued.	Number of octavo pages.	Number of quarto pages.	Total number of pages.
1902........	3	46	....	46
1903........	3	1,667	....	1,667
1904........	11	2,843	34	2,877
1905........	21	3,783	1,445	5,228
1906........	19	3,166	1,288	4,454
1907........	38	6,284	3,428	9,712
1908........	28	4,843	2,485	7,328
1909........	19	3,695	1,212	4,907
1910........	29	3,274	4,831	8,105
1911........	30	5,062	1,670	6,732
1912........	23	3,981	2,044	6,025
1913........	29	6,605	2,752	9,357
1914........	23	4,978	1,934	6,912
Total.......	276	50,227	23,123	73,350

BIBLIOGRAPHY OF PUBLICATIONS RELATING TO WORK OF INVESTIGATORS, ASSOCIATES, AND COLLABORATORS.

Under this heading it is sought to include titles of all publications bearing upon work done under the auspices of the Carnegie Institution of Washington, exclusive of the regular publications. A list of the latter which have appeared during the year will be found in the President's Report (pp. 37, 38).

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REPORT OF THE EXECUTIVE COMMITTEE.

REPORT OF THE EXECUTIVE COMMITTEE.

To the Trustees of the Carnegie Institution of Washington:

GENTLEMEN: Article V, Section 3, of the By-Laws provides that the Executive Committee shall submit, at the annual meeting of the Board of Trustees, a report for publication; and Article VI, Section 3, provides that the Executive Committee shall also submit, at the same time, a full statement of the finances and work of the Institution and a detailed estimate of the expenditures for the succeeding year. In accordance with these provisions, the Executive Committee herewith respectfully submits its report for the year 1913–1914.

During the fiscal year ending October 31, 1914, the Executive Committee held ten meetings, including a joint meeting with the Finance Committee on February 16, 1914. Printed reports of these meetings have been sent to the Trustees of the Institution.

Upon the adjournment of the Board of Trustees on December 12, 1913, the members of the Executive Committee met and organized by the election of Mr. Welch as Chairman for 1914, and by voting that the Assistant Secretary of the Institution act as Secretary of the Committee for the same period.

It becomes the sad duty of the Executive Committee to report the death on January 5, 1914, of Silas Weir Mitchell, a member of the Board of Trustees and of the Executive Committee since the foundation of the Institution, and to record the following resolution passed by the Committee at its meeting of January 15, 1914:

"*Resolved*, That the Executive Committee of the Carnegie Institution of Washington hereby records its deep sense of loss in the severance of warm personal and official relations by the death of Dr. Silas Weir Mitchell. As a Trustee and as a member of the Executive Committee from the foundation of the Institution, Dr. Mitchell has freely devoted to its interests not only a generous share of his time and energy, but also that rare combination of experience, learning, and insight which made him long preeminent as a man of science and as a man of letters. His sympathetic interest in the work of individuals, his versatility in an uncommonly wide variety of researches, and his catholicity of judgment enabled him to render invaluable aid to the Institution during his happily long and continuous service. His fruitful suggestions, his confident optimism, his generous appreciation of the labors of younger men, and his genial courtesy will long be held in grateful remembrance."

We also regret to report the death, on March 11, 1914, of John Lambert Cadwalader, a Trustee of the Institution since 1903.

The President's report gives in detail the results of the work of the Institution for the fiscal year 1913–1914, together with itemized financial statements for the same period and a summary of receipts and

expenditures of the Institution to date. The President also submits various recommendations and suggestions, and an outline of suggested appropriations for the year 1915. The Executive Committee hereby approves the report of the President and his recommendations as the report and recommendations of the Committee.

The Board of Trustees at its meeting of December 12, 1913, appointed the American Audit Company to audit the accounts of the Institution for the fiscal year ending October 31, 1914, and the report of this company is herewith submitted as a part of the report of the Executive Committee.

There is also submitted a balance sheet, showing the condition of the assets and liabilities of the Institution on October 31, 1914, together with statements of receipts and disbursements for the fiscal year and of aggregate receipts and disbursements since the organization of the Institution on January 28, 1902.

Three vacancies in the Board of Trustees, occasioned by the resignation of Mr. Gage, by the death of Mr. Mitchell, and by the death of Mr. Cadwalader, call for action at this meeting of the Board of Trustees. In accordance with the provision of the By-Laws, nominations to fill such vacancies have been requested and submitted to the members of the Board of Trustees.

A vacancy in the membership of the Executive Committee exists by reason of the death of Mr. Mitchell; and the terms of office of Mr. Flexner and Mr. Walcott, as members of the Committee, expire at the coming annual meeting.

William H. Welch, *Chairman*.
Cleveland H. Dodge.
Simon Flexner.
Wm. Barclay Parsons.
Elihu Root.
Charles D. Walcott.
Robert S. Woodward.

November 19, 1914.

Balance Sheet, October 31, 1914.

ASSETS.

Investments:		
Securities (p. 58)		$23,246,247.17
Property Account:		
Real estate, equipments, and publications (p. 59)		2,315,992.61
Current Assets:		
Cash (p. 56)	$394,092.38	
Stamps and petty cash	300.00	
Income receivable (1914)	123,877.74	
		518,270.12
		26,080,509.90

LIABILITIES.

Endowment Fund:		
Endowment	$22,000,000.00	
Profit from redemption of bonds	120,000.00	
		$22,120,000.00
Sundry Reserve Funds:		
Reserve fund	1,070,212.46	
Insurance fund	110,977.82	
		1,181,190.28
Invested in Property		2,315,992.61
Current Liabilities:		
Large grants (p. 59)	213,938.17	
Minor grants	52,102.17	
Publication	71,812.60	
Administration	18,825.53	
		356,678.47
Unappropriated Fund		106,648.54
		26,080,509.90

Receipts and Disbursements from November 1, 1913, to October 31, 1914.

RECEIPTS.

Interest from—		
Endowment—		
Bonds	$1,105,084.17	
Bank balance	15,374.41	
		$1,120,458.58
Reserve Fund—		
Bonds	38,382.50	
Bank balance	888.28	
		39,270.78
Insurance Fund—		
Bonds	4,551.94	
Bank balance	101.50	
		4,653.44
Sales of Publications:		
Index Medicus	5,079.16	
Year Book	49.65	
Miscellaneous books	6,273.59	
		11,402.40
Refund on Grants:		
Grant No. 866	2,870.00	
884	39.79	
931	368.80	
874	250.00	
943	8.00	
862	113.83	
936	3,300.00	
807	65.39	
890	23.73	
743	490.00	
933	2.40	
942	287.76	
		7,819.70
Miscellaneous:		
Refund, building	7.52	
shipping	111.79	
printing, paper, copper	912.09	
bond commission	1,274.37	
		2,305.77
Redemption and Sale of Bonds:		
U. S. Steel Corporation		575,000.00
		1,760,910.67
Balance from last report to Executive Committee		509,278.10
		2,270,188.77

*Including Year Book.

DISBURSEMENTS.

Investment:		
Bonds and expenses		$861,915.73
Grants:		
Large	$817,894.52	
Minor	107,456.05	
		925,350.57
Publication		44,670.55
Administration:		
Trustees	3,108.53	
Executive Committee	1,121.47	
Salaries	26,230.00	
Publication—shipping expenses	4,366.25	
Surety, rent, telephone	360.04	
Equipment	680.08	
Stationery	226.08	
Postage, express, etc	416.88	
Printing	*3,549.55	
Office supplies and petty expenses	849.53	
Building and grounds—		
Supplies and janitor service	2,359.05	
Fuel, light, water	892.08	
		44,159.54
		1,876,096.39
Cash:		
United States Trust Co. of New York—		
Drawing account	329,217.86	
Endowment fund	1,796.20	
Reserve fund	52,890.84	
Insurance fund	256.07	
National City Bank of New York	6,074.94	
American Security and Trust Co., D. C.	3,856.47	
		394,092.38
		2,270,188.77

Aggregate Receipts and Disbursements from Organization, January 28, 1902, to October 31, 1914.

RECEIPTS.

INTEREST:		
Endowment bonds	$8,783,439.17	
Reserve fund bonds	78,586.25	
Insurance fund bonds	7,580.94	
Income and building fund bonds	95,629.06	
Deposits in banks	127,164.19	
		$9,092,399.61
SALES OF PUBLICATIONS:		
Index Medicus	45,699.48	
Year Book	767.06	
Miscellaneous	47,199.70	
		93,666.24
REFUND ON GRANTS		26,943.21
MISCELLANEOUS:		
Organization	1,825.52	
Sale of furniture	87.00	
Postage, express, and travel	56.65	
Printing and paper	4,232.18	
Sale of metal cuts	77.40	
Refund, shipping	487.15	
office	59.43	
insurance	4,717.60	
telephone and light	34.89	
trustees	57.03	
building	68.53	
bond commission	1,274.37	
		12,977.15
REDEMPTION AND SALE OF BONDS:		
U. S. Steel Corporation	920,000.00	
Northern Pacific-Great Northern	48,000.00	
Northern Pacific	102,750.00	
Atchison, Topeka and Santa Fe	49,500.00	
Lake Shore and Michigan Southern	47,000.00	
Central Pacific	48,250.00	
		1,215,500.00
		10,441,486.21

DISBURSEMENTS.

INVESTMENT:		
Bonds and expenses	$2,363,068.41	
Administration building and site	309,915.69	
		$2,672,984.10
GRANTS:		
Large	5,083,192.79	
Minor	1,282,033.92	
		6,365,226.71
PUBLICATION		460,701.07
ADMINISTRATION:		
Trustees	28,793.67	
Executive Committee	20,223.93	
Honorariums to advisers	17,319.81	
Salaries	327,558.03	
Publication—shipping expenses	20,722.56	
Rent, surety, telephone	29,594.20	
Equipment	13,756.56	
Stationery	12,444.78	
Postage and express	19,883.75	
Printing	*31,690.43	
Office expenses	4,120.52	
Building and grounds—		
Supplies and janitor service	10,837.11	
Fuel, light, water	3,811.55	
Organization (1902)	1,825.52	
Plans and option (1902)	5,166.46	
Seal (1903)	555.60	
Miscellaneous	70.23	
		548,374.71
REFUND:		
Publication	20.25	
Index Medicus	86.99	
		107.24
		10,047,393.83
CASH IN BANKS (p. 56)		394,092.38
		10,441,486.21

*Including Year Book.

Schedule of Securities.

Par value.	Securities.	Investment value.	Total.
	ENDOWMENT.		
$10,000,000	U. S. Steel Corporation, Series B, registered 50-year 5 p. ct. gold bonds, due Apr. 1, 1951	$10,000,000.00	
1,200,000	U. S. Steel Corporation, Series A, registered 50-year 5 p. ct. gold bonds, due Apr. 1, 1951	1,200,000.00	
2,500,000	U. S. Steel Corporation, Series C, registered 50-year 5 p. ct. gold bonds, due Apr. 1, 1951	2,500,000.00	
2,500,000	U. S. Steel Corporation, Series D, registered 50-year 5 p. ct. gold bonds, due Apr. 1, 1951	2,500,000.00	
2,500,000	U. S. Steel Corporation, Series E, registered 50-year 5 p. ct. gold bonds, due Apr. 1, 1951	2,500,000.00	
2,500,000	U. S. Steel Corporation, Series F, registered 50-year 5 p. ct. gold bonds, due Apr. 1, 1951	2,500,000.00	
175,000	Chicago, Milwaukee & Puget Sound Rwy. Co., first mortgage 4 p. ct. gold bonds, due Jan. 1, 1949	159,268.00	
13,000	Chicago, Milwaukee & St. Paul Rwy. Co., general mortgage 4½ p. ct. gold bonds, due May 1, 1989	12,935.00	
325,000	Lehigh & Lake Erie R. R. Co., first mortgage 4½ p. ct. 50-year gold bonds, due Mar. 1, 1957	331,568.30	
237,000	New York City, 4½ p. ct. registered bonds, due Mar. 1, 1963	253,557.50	
150,000	South & North Alabama R. R. Co., consolidated mortgage, 5 p. ct. bonds, due Aug. 1, 1936	160,875.00	$22,118,203.80
	INSURANCE FUND.		
28,000	American Telephone and Telegraph Co., 4½ p. ct., convertible bonds	28,978.00	
50,000	Atchison, Topeka & Santa Fe Rwy. Co., general mortgage, 100-year, 4 p. ct., registered gold bonds, due 1995	50,056.25	
6,000	Baltimore & Ohio R. R. Co., 1-year, 4½ p. ct., secured gold coupon bearer notes, due June 1, 1915	5,932.50	
25,000	Bell Telephone Co. of Canada, debenture 5 p. ct. bonds, due Apr. 1, 1925	24,760.00	
1,000	Chicago, Milwaukee & St. Paul Rwy. Co., general mortgage, 4½ p. ct. gold bonds, due May 1, 1989	995.00	110,721.75
	RESERVE FUND.		
50,000	American Telephone and Telegraph Co., collateral trust 4 p. ct. bonds, due 1929	45,500.00	
96,000	American Telephone and Telegraph Co., 4½ p. ct. convertible bonds	99,456.25	
20,000	Baltimore & Ohio R. R. Co., 1-year 4½ p. ct. secured coupon bearer notes, due June 1, 1915	19,762.50	
50,000	Central Pacific Rwy. Co., first refunding mortgage 4 p. ct. registered gold bonds, due 1949	48,250.00	
15,000	Chicago, Milwaukee & St. Paul Rwy. Co., general mortgage 4½ p.ct. gold bonds, due May 1, 1989	14,925.00	
15,000	Great Northern Rwy. Co., first and refunding mortgage 4¼ p. ct. bonds, due 1961	15,227.00	
155,000	General Electric Co., 5 p. ct. gold debenture bonds	158,213.47	
280,000	Interborough Rapid Transit Co., first refunding mortgage 5 p. ct. bonds, due 1966	276,701.00	
50,000	Lake Shore & Michigan Southern Rwy. Co., registered 25-year 4 p. ct. gold bonds, due Sept. 1, 1928	47,000.00	
50,000	Long Island R. R. Co., refunding mortgage 4 p. ct. bonds, due 1949	48,285.00	
50,000	City of New York, 6 p. ct. coupon bearer revenue bonds, due Sept. 1, 1916	50,875.00	
50,000	New York, Westchester & Boston Rwy. Co., first mortgage 4½ p. ct. bonds, due 1946	49,187.50	
50,000	Northern Pacific-Great Northern (Chicago, Burlington & Quincy collateral), joint 4 p. ct. bonds, due 1921	49,876.40	
50,000	Oregon-Washington Railroad & Navigation Co., first and refunding 4 p. ct. mortgage bonds, due 1961	46,375.00	
50,000	United Fruit Co., 4-year, 5 p. ct. gold coupon bearer notes, due May 1, 1918	47,687.50	1,017,321.62
23,241,000			23,246,247.17

Schedule of Real Estate, Equipment, and Publications.

ADMINISTRATION:		
Building, site, and equipment		$331,980.61
PUBLICATIONS:		
Stock on hand (Oct. 31, 1914)	$229,564.20	
Outstanding accounts (Oct. 31, 1914)	2,703.26	
		232,267.46
DEPARTMENT OF BOTANICAL RESEARCH (SEPT. 30, 1914):		
Buildings, office, and operating	45,782.37	
Laboratory equipment	9,431.43	
		55,213.80
DEPARTMENT OF EXPERIMENTAL EVOLUTION (SEPT. 30, 1914):		
Buildings, office, and library	101,547.42	
Laboratory apparatus	6,767.24	
Operating appliances and grounds	18,397.01	
		126,711.67
GEOPHYSICAL LABORATORY (SEPT. 30, 1914):		
Building, library, operating appliances	119,296.87	
Laboratory apparatus	71,947.70	
Shop equipment	15,019.66	
		206,264.23
DEPARTMENT OF HISTORICAL RESEARCH (SEPT. 30, 1914):		
Office	1,706.15	
Library	2,723.14	
		4,429.29
DEPARTMENT OF MARINE BIOLOGY (SEPT. 30, 1914):		
Vessels	32,325.40	
Buildings, docks, furniture, and library	11,328.56	
Apparatus and instruments	4,728.38	
		48,382.34
DEPARTMENT OF MERIDIAN ASTROMETRY (APR. 30, 1914):		
Apparatus and instruments		2,394.34
NUTRITION LABORATORY (SEPT. 30, 1914):		
Building, office, and shop	116,493.69	
Laboratory apparatus	18,965.26	
		135,458.95
MOUNT WILSON SOLAR OBSERVATORY (AUG. 31, 1914):		
Buildings, grounds, road, and telephone line	195,557.11	
Shop equipment	36,134.35	
Instruments	378,247.36	
Furniture and operating appliances	81,380.20	
Hooker 100-inch reflector	183,929.77	
		875,248.79
DEPARTMENT OF TERRESTRIAL MAGNETISM (SEPT. 30, 1914):		
Building, site, and office	126,507.28	
Vessel and survey equipment	121,237.73	
Instruments, laboratory, and shop equipment	49,896.12	
		297,641.13
		2,315,992.61

REPORT OF AUDITOR.

WASHINGTON, D. C., *November 20, 1914.*

The Executive Committee, Carnegie Institution of Washington.

GENTLEMEN: The books and accounts of the Carnegie Institution of Washington have been audited by us from November 1, 1913, to October 31, 1914, by authority of the Board of Trustees. We did not, however, audit the books of the various departments, as that is done by the Bursar and his associates, but we did verify the totals as carried from the subsidiary books to the general books.

The income from the investments of the Endowment, Reserve, and Insurance Funds and from other sources has been duly accounted for and expenditures have been authorized and are supported by proper vouchers.

The securities of the Endowment, Reserve, and Insurance Funds were produced to us, the cash in hand was verified by count and the cash on deposit with banks was verified by properly authenticated certificates.

Respectfully submitted.

THE AMERICAN AUDIT COMPANY,
By C. R. CRANMER, *Resident Manager.*

Approved:
F. W. LAFRENTZ, *President.*

Attest:
S. F. LAFRENTZ, *Secretary.*

REPORTS ON INVESTIGATIONS AND PROJECTS.

The following reports and abstracts of reports show the progress of investigations carried on during the year, including not only those authorized for 1914, but others on which work has been continued from prior years. Reports of Directors of Departments are given first, followed by reports of recipients of grants for other investigations, the latter arranged according to subjects.

DEPARTMENT OF BOTANICAL RESEARCH.*

D. T. MacDougal, *Director*.

The researches carried on by the members of the staff, collaborators, and research associates have chiefly concerned problems upon which some progress has been made previously. The greater part of the work of the Department is carried on at the Desert Laboratory. But little established knowledge of the surfaces of arid regions is available, and the prevalent methods of meteorology do not obtain facts capable of ready analysis in a manner suitable for correlation with physiological experiments. It is therefore necessary to carry out extensive calibrations of the physical features of both the substratum and the atmosphere, although such activities are only incidental to botanical science.

The completion of the photo-chemical laboratory makes available facilities for a study of light in its relations to organisms in a manner and with a thoroughness not hitherto attempted. Similar small, inexpensive, but suitably designed buildings, with adequate equipment, will best serve the needs of workers upon other groups of problems within the scope of the Department, as illustrated by the account of the detailed activities described below.

EREMOGRAPHY OF CLOSED DRAINAGE SYSTEMS.

The comprehensive study of the Salton Sea and the surrounding region in the Cahuilla Basin, begun in 1906, was brought to an advanced stage in 1913, and the result was described in Publication 193 of the Carnegie Institution of Washington, issued in June 1914.

Some of the problems taken up in this region include phenomena of such general importance and wide occurrence that their study is being continued, both in the region in question and in the desert basins to the northward in California, Utah, and Nevada.

It has become evident that a detailed study of the decaying drainage system of the Mohave, tributary to the Death Valley basin in California, would yield some conclusions of the greatest value as to the climatology, surface geology, and ecology of desert basins. Plans are now taking shape for such a survey, and the Director, in company with various collaborators, has traversed the Mohave Desert, Owens Valley, Deep Springs Basin, some of the Amargosa drainage, the basin of ancient Lahontan, and the Washoe Valley, in a reconnaissance preliminary to the organization of this work. The results of this phase of the activity of the Desert Laboratory are given below.

*Situated at Tucson, Arizona. (For previous reports see Year Books Nos. 2-12.)

Eighth Annual Analysis of the Salton Sea Water, by A. E. Vinson.

The level of the water in Salton Lake fell 54 inches during 1913 and the recession from June 1, 1913, to June 1, 1914, the period separating the taking of the water samples for the two years, amounted to but 42 inches, according to data furnished by the Southern Pacific Railway. A constant level was maintained from December 1, 1913, to May 1, 1914, which was probably due to the equivalence of inflowing flood-stems water to the evaporation.

The annual sample of Salton Sea water was collected June 12, 1914, over deep water about 1½ miles from shore, near Travertine Point. The water was very clear and did not show as many organisms as were present the previous year. The lime deposits on the mesquite stems below water-level did not seem as heavy as in 1913.

During 359 days (June 18, 1913, to June 12, 1914) the total solids have increased from 1,002.56 to 1,179.6 parts per 100,000, an increase of 17.5 per cent. When calculated for the year ending June 31, 1914, by the method used in previous years, the annual concentration is found to be 18.1 per cent (17.7 per cent for 1913 and 17.5 per cent for 1912). The table gives the composition on June 12, 1914.

	Parts in 100,000.		*Parts in 100,000.*
Total solids (dried at 110° C.) plus water of occlusion and hydration	1,179.6	Lithium, Li	None.
Water of occlusion and hydration	36.2	Chlorine, Cl	559.66
Sodium, Na	381.47	Sulphuric, SO_4	148.10
Potassium, K	4.01	Carbonic, CO_3 in total solids	None.
Calcium, Ca	22.22	Carbonic, CO_2 total	10.68
Magnesium, Mg	19.03	Bicarbonic, HCO_3 volumetric	15.22
Aluminum, Al	0.140	Silicic, SiO_4	2.42
Iron, Fe	0.012	Phosphoric, PO_4	Trace.
Manganese, Mn	None.	Nitric, NO_3	None.
Zinc, Zn	None.	Nitrous, NO_2	None.
Lead, Pb	None.	Oxygen consumed	0.110
Copper, Cu	None.	Boric acid	Trace.

Calcium and carbonates, as in previous years, have not concentrated as much as the other constituents, carbonates again showing an actual decrease. Potassium, however, instead of decreasing has concentrated this year in about the same ratio as the other constituents.

Micro-organisms and Tufa-formation in the Salton and Other Saline Waters, by George T. Moore.

In the first part of May 1914, a trip was made to the Salton Sea for the purpose of securing a collection of the algæ growing in this body of water, as well as obtaining material which might throw light upon the formation of the travertine occurring here and elsewhere. The algæ collected, while of value as indicating the character of the flora of a body of water subjected to the peculiar conditions of the Salton, were not sufficient from which to draw any well-defined conclusions. It is evident that more information could be obtained from material col-

lected earlier in the season, probably in March. In order to form any comprehensive notion of these aquatic plants it probably will be necessary to have samples taken for a number of years to come, or at least until the water has reached an almost stable condition.

One of the problems in connection with the Salton is the process by which the tufa deposits are formed. As pointed out by Jones (Carnegie Inst. Wash. Pub. 193, p. 23) and suggested by Walcott (Smithsonian Miscellaneous Collections, vol. 64), this may be due to algæ, and certainly the evidence collected by Jones strongly supports such a hypothesis. There is also a possibility of the deposition of carbonates being due to bacteria, or indeed it may be the result of the combined action of these two groups of organisms. The only way to understand why and under what circumstances tufa is deposited, with the solution of the various other problems involved, is to discover by what organism and in what way the bicarbonates present are decomposed and the resulting carbonates laid down in the characteristic tufa formation. Good material for an investigation of this point was obtained at the Salton Sea, but the most promising collection was made near Reno, Nevada. Attempts are now being made to isolate in pure cultures some of the algal organisms associated with the forming of tufa, and if this can be done successfully, it may be possible to discover something of the actual processes involved.

The bacterial side of the investigation has been delegated to Mr. Karl F. Kellerman, of the United States Department of Agriculture. The samples thus far furnished him have been insufficient to enable him to draw any definite conclusions.

Origin of the Tufa Deposits of the Interior Basins, by J. C. Jones.

The work begun in the Salton Sink has been carried to the basin of Lake Lahontan and it has been found that the blue-green algæ and associated bacteria are probably concerned in some manner with the deposition of most of the tufa found in the latter basin. Remnants of algæ have been found in all the Lahontan tufas, except the thinolitic form, and while the relation between the development of tufas and the light exposure is not so evident as in the Salton, yet in all other respects the evidence is essentially the same in the two basins. The tufa forming at present in Pyramid Lake is lithoid in character, apparently on account of the low content of calcium of the lake waters. Laboratory experiments have been started through the cooperation of Dr. G. T. Moore, in which it is hoped to develop tufas under controlled conditions.

Measurements of the more perfect thinolite crystals indicate aragonite as the original mineral. It has been found that calcium carbonate is deposited from the water of Pyramid Lake as aragonite when a saturated solution of calcium bicarbonate is added.

As the history of Lake Lahontan is largely to be determined by our knowledge of the origin of its calcareous deposits, the evidence bearing on the history of this lake has been reviewed and conclusions differing somewhat from those of Professor Russell have been reached. It seems highly probable that Lahontan has never been completely desiccated and that Pyramid Lake is a remnant of the older lake.

An estimate of the age of Pyramid Lake, based on its present saline content, indicated that Lahontan originated about 4,500 years ago. The finding of the bones of a horse, lion, and camel, similar to those

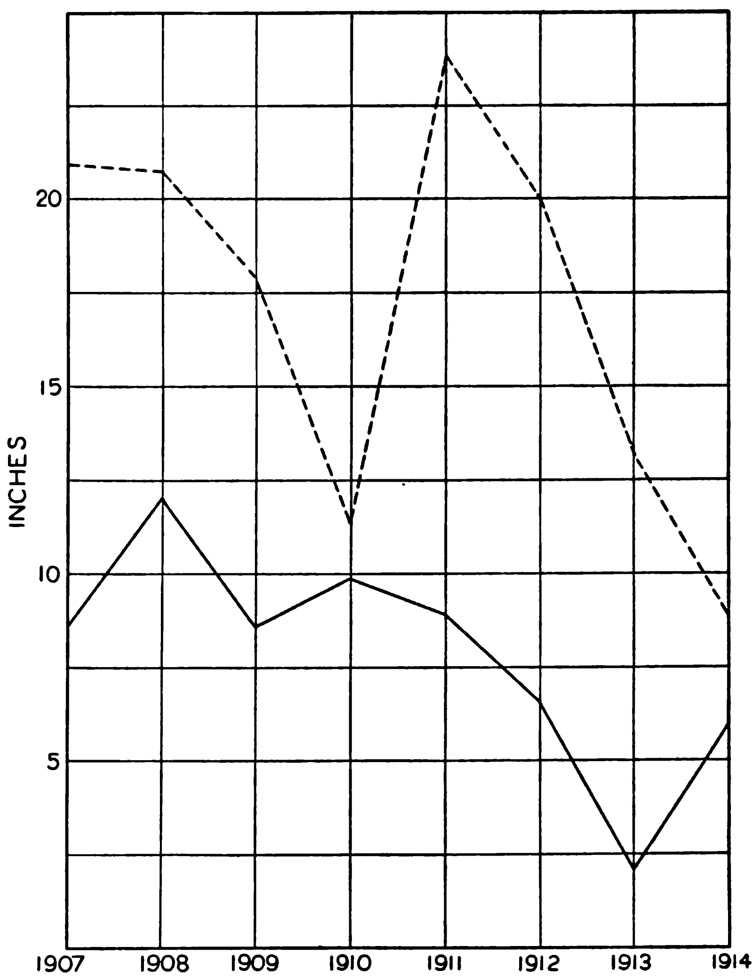

FIG. 1.—Curves showing the amounts of summer rainfall at the Desert Laboratory (solid line) and at an elevation of 8,000 feet in the Santa Catalina Mountains (broken line), covering a period of eight years. The amounts for 1914 are to the end of July only.

occurring in the asphalt beds at the Rancho La Brea near Los Angeles, in the deposits of Lake Lahontan, has raised the interesting possibility of the continuance of this fauna well into the Recent period in Nevada.

Progress in the Measurement of the Physical Factors of an Isolated Desert Mountain, by Forrest Shreve.

Instrumental observations have been continued at the seven stations extending from 3,000 to 9,000 feet on the Santa Catalina Mountains, from six of which data have now been secured for four years. The readings include the summer rainfall and the absolute minimum temperature at the seven stations, together with the absolute maximum temperature at 8,000 feet. The soil-moisture on both north and south slopes at the seven stations is determined for the period of its annual minimum in the arid fore-summer, and the absolute maxima and minima of soil temperature have also been secured during the past year. The soil-moisture on north slopes at 9,000 feet is approximately as great at the time of its annual minimum as it is on the desert at the time of its annual maximum. The absolute minimum temperatures at the highest stations are found to be much higher than the absolute minima for the same winters at stations of the Weather Bureau which are located at the same elevations on the Mogollon Plateau in central Arizona, indicating that the isolated desert ranges present less severe winter conditions than do the extended plateaus of the same elevation in nearly the same latitude. The minimum soil temperatures at all of the stations are found to range much higher than the atmospheric minima at the same stations, a condition of great importance in the growth activities of plants.

The record of rainfall at 8,000 feet now extends through eight summers and affords a striking contrast to the summer rainfall at the Desert Laboratory, not only in its amount, but in the lack of relation between the annual fluctuations in the two localities, which are separated by a vertical distance of 5,300 feet and a horizontal distance of 20 miles. The evidence is becoming more conclusive from year to year that the rainfall at 9,000 feet will prove to be less, on a long average, than that at 8,000 feet. (Fig. 1.)

Comparison of the Vegetational Gradients of Isolated Desert Mountains, by Forrest Shreve.

The work on the correlation of vegetation and climate in the Santa Catalina Mountains, which has been under preparation for publication during the year, has been extended by an examination of several other isolated desert mountain ranges in southern Arizona. The object has been to discover the possible influences of the character of the underlying rock and its soil in causing departures from the distributional

behavior which has been found in the Santa Catalina Mountains, which present a uniform type of gneiss from base to summit; and also to determine the indirect effect which the total height of mountains exerts upon the gradient of vegetation presented by their slopes. It has been found, in general, that the vegetation at a given elevation near the summit of a low range is much more desert than it is at the same elevation on the slopes of a higher range. The instrumentation carried out on the Santa Catalina Mountains, when interpreted in terms of the topographic configuration of the range, indicates that the rainfall is heavier at 5,000 feet, for example, on the slopes of a 9,000-foot mountain than it is at 5,000 feet on the summit of a lower range. Furthermore, the absence of cold-air drainage on the summits of low mountains, as compared with the slopes of higher ones, causes marked differences in the temperature conditions which obtain at the same altitudes in mountains of different elevation.

These explorations are yielding a broader basis for our knowledge of the correlation of vegetation and climate and are gradually affording the materials for a classification of vegetational regions more satisfactory than that which is now in use, while they also suggest definite lines of instrumentation to be taken up in connection with further work.

The Annual March of the Ratio of Evaporation to Soil Moisture, by Forrest Shreve.

Data have been elaborated and published which comprise the weekly percentages of soil moisture at three depths, the concurrent weekly evaporation, and the ratio of the evaporation to the moisture of the soil at the lowest of the three depths sampled. The soil investigated was the heavy clay of Tumamoc Hill. The weekly values of the ratio obtained are a concise expression of the complex of soil and atmospheric conditions by which the water relations of desert plants are controlled. Their value as a criterion of climatic conditions lies in the fact that they express both the soil and atmospheric conditions, and much more precisely than would a ratio of rainfall to evaporation. The highest figures for the ratio—which indicate the least favorable conditions for vegetation—are secured in the arid periods which precede and follow the summer rainy season, while the lowest values are obtained in the winter months. The annual maximum value obtained was 110, the minimum 11.5, indicating an annual amplitude of moisture conditions under which the winter is approximately ten times as favorable as the arid portions of the summer. The annual fluctuation of moisture conditions at the Desert Laboratory exhibits extremes, in other words, which are as great as those found between the desert valleys and the forested mountain summits of southern Arizona. (See Ann. Rept. Dept. Bot. Research, p. 59, 1912.)

Superposed Bajadas in the Great Basin Region, by E. E. Free.

It is customary to regard the bajadas or bordering detrital aprons of the arid-region mountains as smoothly graded slopes produced by the slow and uniform accumulation of mountain débris. Closer study upsets this conception. In nearly every case deeply cut washes and isolated erosion remnants indicate that the slopes have been regraded more than once and that bajadas of different age have been superposed. It appears that these superposed bajadas correspond to the alluvial terraces and hanging deltas of the mountain valleys described by Huntington[1] as the result of climatic fluctuations. The superposed bajadas are at least four in number and appear to possess certain individual characteristics which are quite persistent over the whole Great Basin region. For instance, the third of the series (the sub-Recent one) forms the main body of the detrital slopes. It is furrowed by wide, flat-bottomed washes, almost always with an intermediate erosion terrace not far below the top. These washes debouch onto the lower, flatter, and more recent bajada, which is also cut by washes, but of a different type, being deeper, narrower, and without the intermediate terrace. These two younger bajadas are entirely slopes of aggradation. The two older bajadas are represented by remnants only and these are frequently rock in place, and have resulted from erosional planation rather than aggradation. The chief interest of these and other individual characteristics of the bajadas lies in their persistence in many parts of arid North America under widely varied local conditions, and it seems not impossible that closer study of these characteristics will yield important evidence as to the post-glacial climate of the region.

ANALYSIS OF THE EFFECT OF CLIMATIC COMPLEXES, AND SEPARATE EXTERNAL FACTORS.

The number of species of plants which have been found to endure the widely varying climates of the Montane plantation (8,000 feet), Xero-montane plantation (5,400 feet), Desert Laboratory (2,300 to 2,700 feet), and of the Coastal Laboratory station was noted last year as under a score. The total census of these plantations, however, now runs nearly to a hundred, and twice as many have been dealt with in securing this number of survivals. The most notable fact that has come out of this work so far is that although a majority of the species have matured seeds or perfected propagative bodies, not one has yet been disseminated beyond the limits of small plantations in which they have been placed. A general record receives all of the climatological and ecological facts of importance in the history of the plantations, and the history of all material is made available to the collaborators who undertake problems and use this material for experimental purposes.

[1]Especially, Bull. Geol. Soc. Amer., 18, 351–388 (1907); Carnegie Inst. Pub. 192, 23–36 (1914).

Auxo-thermal Integration of Climatic Complexes, by D. T. MacDougal.

It is obvious that if we are to make any rational interpretation of the partial and totalized effect of temperature upon the organism in any phase of its activity, or during all of its ontogeny, a method must be formulated by which the duration and intensity of the temperature exposure of the organism may be calculated.

The author's work led him in 1900 to a realization of the necessity for such a method, and the first attempts at anything definite were presented at the Denver meeting of the American Association for the Advancement of Science in 1901. The method then proposed consisted simply in estimating the number of hours at which the temperature stood above the freezing-point from the beginning of a season until a plant had attained a certain stage of its development. This method was superior to all previous methods of summation of temperature effects, in that it gave full value to the time factor of exposure, which the older methods of cumulating or totalizing maxima or averages of daily temperatures did not. It implied an empirical procedure, as growth at all temperatures above the freezing was taken as uniform.

The first step in the selection of a standard by which the constructive processes of organisms might be measured consisted in fixing upon some form of activity which was delicately affected by temperature and was readily measurable. Growth extension or expansion seemed to meet these requirements most fully, and this selection had the additional advantage that a large number of measurements of the actual rate in several species is already available.

It was therefore determined that evaluation of climatic factors of any kind must necessarily be made in terms of some single plant, or as may fall out later in groups of plants with similar procedure. Next it was seen that the data which might be obtained by the measurement of the elongation of internodes in a monocotyledonous stem would be more easily secured and corrected and could hence be made more exact. A plant of this kind with a range from the tropics to the arctics was represented by wheat and the growth-data of this plant was already available, enabling us to measure the temperature factor of a climate in terms of the growth velocity of wheat, as it might be done with any other plant the growth of which has been determined.

Assuming now that it is desired to evaluate the variable temperature of any place or of any experimental setting, it is first of all necessary to secure a reliable thermograph record for the period under investigation, which might include the entire frostless season or the time in which a certain stage of development of the selected organism had been accomplished. Next this record is ruled by lines which will divide it into figures, the area of which (measured by a planimeter) represent the length of time and intensity of temperature. The obvious procedure is simply to construct regular figures which shall include the area of the

thermographic diagram as nearly as possible and to make these figures of such size that the use of averaged rates of growth will include the smallest practicable error. Crude as this method may appear in this preliminary form, it is based upon actual procedure, and all of its essentials are capable of correction; its use at the Desert Laboratory gave the following values for January in three successive years:[1]

Time.	Temp.	Time × temperature.	Rate of growth.	Total growth values.
January 1912	40–65° F.	120.4	× 4.5 ×.8	433.4
	65–70	20.3	×20 ×.8	324.5
	70–75	18.6	×45 ×.8	669.6
	75–80	5.5	×70 ×.8	318.0
Total...	....	164.8		1745.5
January 1913	40–65° F.	87.7	× 4.5 ×.8	315.7
	65–70	21.9	×20 ×.8	350.4
	70–75	17.1	×45 ×.8	615.6
	75–80	1.4	×70 ×.8	78.4
Total...	....	128.1		1360.1
January 1914	40–65° F.	109.3	× 4.5 ×.8	395.5
	65–70	16.5	×20 ×.8	254.0
	70–75	13.3	×45 ×.8	478.8
Total...	....	139.1		1128.3

Responses of Phytolacca decandra to Various Environmental Conditions, by Francis E. Lloyd.

The species upon which this investigation is based is the familiar poke-weed, *Phytolacca decandra*, widely distributed throughout eastern North America, and until now regarded as homogeneous taxonomically. Material has been grown in Arizona (at Tucson and at the Montane plantation, Santa Catalina Mountains) and in California, at Carmel, thus affording exposure to marked climatic extremes. The natural absence of this species from both these localities gives hope of answering the question as to its failure to establish itself therein.

Responses of vegetative organs.—While it has become evident that the now recognized species is not homogeneous as to leaf-structure, it is sufficiently clear that the plant, when introduced into new environment, shows distinct responses in change in leaf-structure, together with alterations in habit. At Carmel the low summer temperatures induce vegetative growth at the expense of fructification, disturbance in growth-rates (resulting in the distortion of leaf-tissues), and in the general metabolism, causing very early a blotchy discoloration passing through yellows to deep crimson. Even very young leaves are affected.

[1] See MacDougal: Auxo-thermal integration of climatic complexes. American Jour. of Bot., vol. 1, pp. 186–193, 1914.

Perennation of the above-ground shoots is here possible. At Tucson, a lax, even prostrate, habit has become evident, the leaves appear normal in color and shape, and flowering and fruiting are abundant. In both situations there is considerable thickening of the leaf, expressing itself both in an increase in the number of layers of cells and in their enlargement and subdivision. Since these characters are appreciable and measurable, it becomes possible to test the effect of environment on the soma in terms of inheritance.

Floral behaviors.—At Carmel the climatic conditions of the late spring and summer are unfavorable for the development of flowers. Flower-buds are formed, and the inflorescence may appear, only to be arrested before any anthesis. Inflorescences 2 cm. long have been observed to remain unchanged for over three months, while the shoots bearing them advance in growth. During the present summer only one inflorescence normal in form and color was produced, but in this the perianths did not spread open, though the stigmas were exposed and pollinated. In spite of the latter circumstances, there is no indication that seeds will be produced. Plants growing under a well-ventilated glass shelter produced normal flowers, and the prompt enlargement of the ovaries indicates that seeds will develop. This shelter preserves the temperature a few degrees centigrade (2 to 4) above the usual ones prevalent on foggy days, and gives protection from the cool winds. It may be concluded that the failure to form normal flowers and seeds during this time of the year results from the too low temperatures.

Marked departures from the normal have been shown by two out of five old plants which have been allowed to persist at Tucson. One of these (No. 2) in 1913 produced only abnormal inflorescences, in which the flowers remained in the form of minute vegetative buds in the axils of the bracts and bracteoles, which were much hypertrophied, and the branching system had been advanced from simple to compound. Another plant (No. 1) showed similar structures on a single basal branch in 1913.

The shoots formed in 1914 on these plants showed additional alterations, consisting chiefly of insect galls; the double effect was exhibited by every inflorescence on plant No. 2, while a few normal racemes were formed on No. 1. The gall is due to the stimulation of the pistil by an unidentified and possibly new insect. Indeed, two insects have been found within the galls, one cynipidous, the other gnat-like, in separate locules of the same pistil. There is also always present a fungus which lines the cavity, and the frequent occurrence of mummies of larvæ indicates that the fungus is parasitic on the insect or insects and not on the plant, since it is not found in otherwise unoccupied ovaries. The inference that this whole abnormal behavior is referable to insect stimulation is possible, but is not supported by the evidence at present available. For example, very young inflorescences in which total suppression of flowers has occurred show no trace

of insect work, which, if it had obtained at all, must have been effective on the unopened flower-bud, or even the growing apex. Again, galls are produced in both normal and abnormal ovaries, or may be absent from both, though it should be added that the absence of a gall does not preclude entirely the presence of wound response, which may or may not have been caused by the insects, either or both.

The morphological departures from the normal, aside from the formation of galls, include antholyses in various expressions, among which may be mentioned separate pistils, conjoined and open pistils, the occurrence of a gynophore, flowers superimposed in series, phyllody of stamens and replacement of ovules by shoots in the axils of the carpel, together with intergradations between those and perfect ovules. A study of the series supports the view that the ovule in *Phytolacca* is the homologue of a shoot, of which the first leaf is decurrent and constitutes the outer integument. The inner integument is apparently compound of two or more connate leaves, while the nucellus is the vegetative apex, normally of the chief axis but teratologically sometimes of a branch. The embryo-sac may be entirely absent or may be present. The megaspore has been observed in both chief and secondary growing-points of shoot-like ovules. This interpretation in its general form is not a new one, but the material is of such variety morphologically as to make it possible to throw new light on the origin of the integuments. (Fig. 2.)

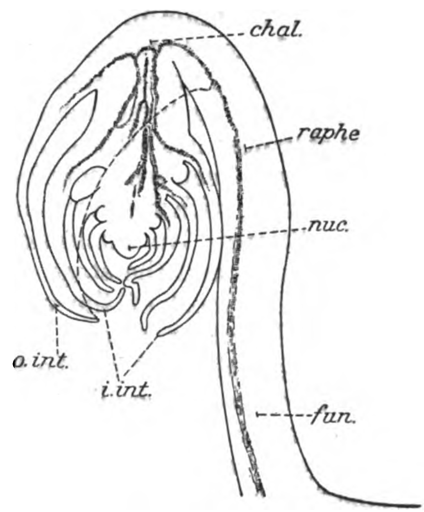

FIG. 2.—Vegetative shoot replacing an ovule in *Phytolacca* (Tucson, No. 1). The parts of the normal ovule correspond to the parts indicated as follows: *o. int.*, *i. int.*, outer and inner integument; *chal.*, chalasa; *fun.*, funicle; *raphe*. The margin of the outer integument is indicated by a broken line.

The galls show a fleshy hypertrophy of the pericarp and of the ovules, which, when fundamentally normal in form, may display enlargement of parts and inflation of the integuments. Though different insects have been found in adjacent carpels, no difference in structure of the galls was visible. The innermost hypertrophied tissue, together with the ovules, constitute the food of the larvæ.

The Determinative Action of Environic Factors upon Neobeckia aquatica Greene, by D. T. MacDougal.

Neobeckia is a water-cress inhabiting the marginal strand of lakes in eastern America below high water-level, which displays a range of leaf forms from oblong-lanceolate, nearly entire blades, to others finely

divided with linear or thread-like divisions. It seemed to offer suitable material for a test of the extent to which the ontogenetic procedure of a plant might be altered by environment, the degree of functional adaptation shown by these changes, and also to promise some evidence upon the nature of regenerative changes which precede reproduction. Cultures under controlled or measurable conditions have been carried on in the New York Botanical Garden, at Cinchona, Jamaica, and in the various plantations of the Department since 1903. The results obtained under these temperate and tropical, moist and arid, mountain and seashore climates, and in aquatic and terrestrial habitats, in a decade may be briefly summarized as follows:

The cultivation of *Neobeckia* as a terrestrial was accompanied by the development of thickened roots, in which an exaggerated formation of cortical and fibro-vascular tissues ensued. Large amounts of starch accumulated in these members, the entire reaction being one which probably does not occur in nature. Variations in the form of nepionic leaves have been seen coupled with the composition of the medium or substratum, with the availability of a supply of food to buds, and with competitions. No connection was established between the form of such organs and the stage of the material taken for rejuvenescence, although in most of the experiences such effects would have been masked by other effects. While it is true that most of the diverse structures exhibited by the leaves of *Neobeckia* show some degree of suitability to the conditions under which they are formed, yet this is by no means always the case, as instanced by the occurrence of terrestrial types in submerged plants. This of course is still more noticeable in the various regenerative proceedings in which the form and structure of the leaves are determined by the presence or abundance of certain formative materials. The form and structure of roots and foliar organs of *Neobeckia* are seen to be determined by environic conditions to a much greater extent than in *Proserpinaca*, *Sium*, or probably any other so-called "polymorphic" species, yet the reaction to such external agencies is not a direct or physical adjustment, and is purely directly resultant. The full detail of this work is given in Flora, vol. 106, pp. 265–280, 1914.

The Role of the Factors of a Desert Complex in Evolution Processes of the genus Leptinotarsa, by W. L. Tower.

The chief point of interest in the investigations at Tucson during the past year concerns the further study of the series of mutating stem stocks produced at Tucson, through the hybrid synthesis of two or more parent species into one invariable form. These, as described in previous reports, remained stable and did not break up, according to the recognized principles of hybrid reactions, and continue to remain

stable, unless subjected to conditions of experiment which induce the mutating behavior. During the past year we have further tested the constancy of these mutant forms and find that they are in the main entirely homozygous, and are constant even in massed cultures. The stem stocks continue to throw off the mutant types in small numbers, and these are being tested at Tucson and also at Chicago.

One culture gave a reaction during the past year that was of much interest. It went into hibernation at the end of 1912, and did not come out at all during the season of 1913, although they were given every opportunity in the way of conditions to do so, but they remained in hibernation until June 1914, when they emerged and gave a strong, fairly numerous progeny, with many mutant types. It is not at all uncommon for some of these forms to remain in hibernation through a year or more, when the environic conditions are severely adverse, but why they should remain in hibernation throughout a season when the conditions were not adverse but favorable is difficult to explain.

In addition to the mutant types that are thrown out in these cultures, most of which are new or recombinations of factors known to have entered into the original combination, the cultures as a whole show two general reactions to the conditions at Tucson that are of considerable interest. As a whole they are showing a loss of color-forming capacity in both the melanoid and lipoid pigments, giving the cultures a distinctly albinic aspect. This, tested in the laboratory at Chicago, is entirely a recessive character when crossed with the normal stocks at Chicago.

A second point of interest is the gradual development in successive generations of changes in the factorial composition of the elytra, giving new pattern arrangements not hitherto known in any of the species from which these experimental series were derived. It is not possible to say at present whether this progressive development of new factors, or of arrangements of factors, is due to the environment or to some series of reactions going on within the gametic material which may be independent of the environment or possibly influenced and driven by the environmental conditions at Tucson. These changes are gametic and stable, but further statements with regard to them must be postponed until test experiments now in progress have been completed.

In general, this series of experiments seems to be in every respect a confirmation of de Vries's mutation behavior, as observed by him in *Oenothera*, with the added showing of how the behavior may be produced. It does not follow that this is the only manner in which the same behavior could be produced. By the end of another season or in two at the most it will be possible to give some exact statements of the factorial composition of these mutant types, and of their relations to the original component species.

In previous Year Books there have been noted the modifications of the antennæ in *L. signaticollis*, which was produced in experiments at Chicago as the result of desert conditions. This year in one of the cultures of our mutant forms we found one female with antennæ having the same type of antennal modification. She is now mated with a normal male and already a large progeny is assured. Whether the change, which is a profound one in an invariable racial character, is gametic or not is not yet known, but it is of extreme interest that this same type of change in the same organ should arise upon two unlike experimental stocks as the result of the impact of essentially the same set of conditions in the medium. That the changes are the direct result of the action of the conditions in a desert complex there can be no justifiable doubt. Of the thousands of specimens of this material that have passed through my hands, in experiment and from nature, no examples of this conspicuous change have been seen, and in the materials stored in the museums in America and Europe there is not to my knowledge a single example of this type of antennal character known in *Leptinotarsa* or in any other species of the phytophagous Coleoptera.

In the reports for 1912 and 1913, progress was noted in the series of experiments concerning the water relations of pure cultures of *L. decemlineata*. During the past year these experiments have been continued and expanded. Cultures that have been at Tucson only four generations failed to pass the winter conditions of 1913–1914 at Chicago, and were entirely eliminated, as were those that had been at Tucson under desert conditions for longer periods. It was found, however, that a culture that was sent to Chicago, and reproduced there, showed the beginning of a reversal of the process, three individuals emerging out of nearly 700 that went into hibernation, and we now have their progeny at Chicago, which will be tested concerning their resistance during the coming winter. Next year we shall be in a position to make preliminary tests to determine, if possible, the nature of this change in these materials when there will be available materials that range from freshly introduced stock to those that have been at Tucson for 15 generations.

All of these stocks of *L. decemlineata* are showing marked gradual movements towards an albinic condition and other indications that the pressure of desert environment is beginning to have an action that may soon show itself in other changes.

The introduction of species from the rain-forests or from the monsoon climate conditions have thus far proved failures, as none have been able to persist for more than a generation. The pure stocks are far more delicate and do not seem to be able to exist at all, but when two are crossed and the F_1 hybrids are introduced, these seem in most experiments to be able to survive and reproduce. During the winter

hibernation the extracted parent forms, however, are entirely or nearly eliminated, and only the heterozygous individuals have thus far been able to breed in F_2 or F_3, and these gradually become weaker and are finally exterminated. In the future we shall try to temper the rigor of the desert conditions during the initial generations, and perhaps by the gradual transition into the desert complex it may be possible to bring about the adaptation of these inhabitants of the moist regions to desert conditions, thus getting important information concerning the processes of adaptation and of the water relations of the inhabitants of arid and moist environmental complexes.

The spherical form of atmometer noted in the reports for 1912 and 1913 continues to justify its adoption for use in these experiments, and the methods of cleaning and operation show that the instrument is fully as sensitive and reliable as a thermometer. Our permanent black cups are specially sensitive, tests at Chicago showing them to be sensitive to the passing of the lightest cloud or even of the shadow cast by one's hat. It is hoped that these instruments can be made available for general use within the year.

The general oversight and care of the experiments has been continued through the year by Mr. J. G. Sinclair.

The Intra-Vitam Absorption of Methylene Blue in the Ovules of Scrophularia, by Francis E. Lloyd.

In order to determine the probable course of absorption consequent upon the injection of stimulatory or other reagents into the living ovaries of seed plants, recourse was had to the following of the relative rates of intra-vitam absorption of methylene blue by the various ovular structures. Two procedures were employed, that of the usual ovarial injection of a 1 to 1,000 solution used by Dr. D. T. MacDougal, and that of allowing sections of the living ovary with attached ovules to lie in weak solutions of the stain. The evidence shows that there is a very definite localization of absorption whereby the reagent in question reaches the egg-apparatus of *Scrophularia*. The small ovule is composed chiefly of the single integument, the innermost layer of which, known as the tapetum, constitutes a special tissue lining a slender cylindrical cavity in which lies the embryo-sac. The end containing the egg-apparatus tapers to form a closed micropyle, while the antipodal end is embedded in the small chalaza, which is peculiar in having cells with thickened walls. (Fig. 3.)

Fertilization is accomplished within 4 to 8 hours after pollination. The course of the pollen-tube is as follows: from the style, the tubes pass down between the placental plates (which are free from each other in the upper part of the ovary) and along the surfaces of the placentas

between the funicles, along these and along the surfaces of the ovules to the micropyle with little indirection. Passing down the micropyle with no destruction of tissues, the tube reaches the egg. The course is therefore ectotropic, a point of importance to be considered when ovarial treatment is used for inducing changes in the organism, and which, in view of the facts derived from work on other Gamopetalæ,[1] must be determined in each particular instance.

Fifteen hours after the injection of the reagent into the ovary (the wound lying within the placenta except at its upper end) the interior cells (but not the epidermis of the placenta and funicles) were fairly deeply stained. Though in some instances there was no visible trace of the dye in the body of the ovule, the fact that dead nucellar or antipodal cells were very deeply colored showed that it had spread farther than was evident to the eye. Other ovules showed a faint but quite distinct coloration of the *walls* of the nucellar cells, while in these or other ovules a portion of the tapetum and the embryo-sac structures, including the egg-apparatus (or sometimes this alone), also revealed color. The same relations were shown by ovules 24 hours after treatment, but in a more pronounced degree, due (in the instance in question) in part to the fact that the fluid found its way into the ovarial cavity. Preparations allowed to remain for 44 hours after injection again showed deep staining only of the funicle, raphe, and nucellus, a few ovules alone showing any color in the embryo-sac and none in the tapetum.

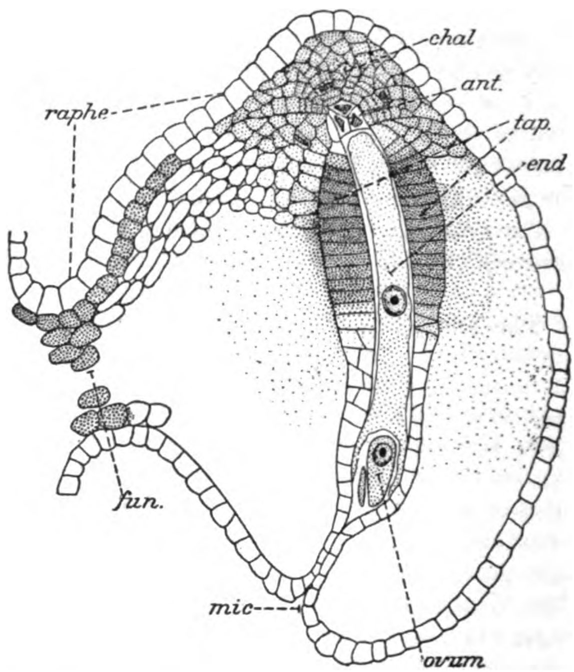

FIG. 3.—Longitudinal section of an ovule of *Scrophularia* (slightly diagrammatic), to illustrate the course of methylene blue and the selective action of the nucellus (*nuc.*) and tapetum (*tap.*); *ant.*, antipodal cells; *chal.*, chalaza; *end.*, endosperm; *fun.*, funicle; *ovum*, or egg-cell; *raphe*, the conductive tissue extending from the funicle to the chalaza. (Drawn by F. E. Lloyd.)

These relations of the ovular tissues to the stain were substantiated by placing sections of the living ovary in a weak solution of the reagent

[1]Lloyd, Mem. Torr. Bot. Club, vol. 8, and elsewhere.

for about 12 hours, when the selective behavior of the tissues was revealed in the clearest manner. In this way it was seen that a transverse zone of tapetal cells (about six cells broad and removed from the antipodal end of the embryo-sac by another zone of equal extent) is very avid of the stain and shows deep coloration, though at the time the endosperm cytoplasm may show none. The micropyle and the tissues surrounding it display under similar conditions no smallest trace of the stain, and progressive staining shows that the stain passes from the chalaza onwards toward the micropyle and not in the reverse direction. The pollen-tubes, however, take up the stain abundantly, and this cytoplasm may be followed with great ease through the micropyle as far as the egg-apparatus.

The above facts indicate with a fair degree of certainty the following conclusions:

(1) When a reagent such as methylene blue is placed within the ovarial cavity it can reach the egg-apparatus by way of the funicle, nucellus, and embryo-sac; the walls of the nucellar cells present a chemical structure which enables them to absorb methylene blue, in contrast to the remaining cell-walls of the ovule. I judge them to be somewhat hydrolyzed.

(2) A restricted zone of the tapetum, as above delimited, has a special function, as evidenced by the very great staining of the protoplasm of its cells. It would seem, however, in view of the appearance of ovules subjected to intra-ovarial staining for 2 days, that for the transfer of the stain the tapetum is of less importance than the nucellus. This inference, based on the relative depth of the stain, may not allow any conclusions as to the relative physiological importance of the tapetum.

(3) If ovaries are injected a few hours after pollination, the reagent may reach the male nuclei and their cytoplasm, and, through the pollen tubes, the egg-apparatus.

(4) The reagent probably reaches the egg-apparatus much more quickly than a visible accumulation of the stain would indicate.

Alterations Induced by Ovarial Treatments of Plants, by D. T. MacDougal.

The fact that seeds matured in ovaries of *Scrophularia*, which had been treated with a dilute solution of potassium iodide, produced two aberrant individuals was noted in the report for 1913. The further cultivation of these perennial plants, and of the second generation, makes possible the following tentative conclusions:

(1) The introduction of solutions into the ovaries of *Scrophularia* may result in affecting the embryo-sac or pollen-tube singly or simultaneously, or the fertilized egg. (See Lloyd, p. 77.)

(2) The effect of the reagent in changing the egg or pollen nucleus separately would lead to the formation of a hybrid by the union of a normal and an altered element.

One of the two derivatives noted above had an F_2 or second generation which was exactly identical with the F_1 or first generation. The other derivative presented a marked disturbance of correlations in the F_1 by which the leaves and flowers were irregular in many features, such as shape, rate of growth, color-patterns, etc., in the first generation, which in the second generation gave way to balanced differences from the parental type, and resulted in individuals not exactly identical with the single parent of the first generation. Both types of departure included a change in color-patterns in flowers, in structure of leaves and stems, and in developmental velocities.

(3) Colored solutions introduced into the ovaries of *Scrophularia* were taken up by the funicular stalks, carried to the nucellus and antipodal regions, and then diffused to the egg-apparatus. It seems probable, therefore, that the reagents producing the departures noted above did so by their action on the egg-nucleus or upon the fertilized egg. The differences between the two derivatives may rest upon the two possibilities noted. (Fig. 3.)

(4) The colloidal complex of living matter includes a great number of closely related unstable compounds giving a wide variety of reactions or transformations. Some of these may be checked or stopped, others facilitated, or new reactions set up by intrusive substances. The compound, potassium iodide, used does not unite with proteins, but exerts a neutralizing or coagulatory action on them. Some departures might be evaluated as losses of characters; others, such as new incisions in corolla limbs and new lateral veins in leaves, are increased differentiations.

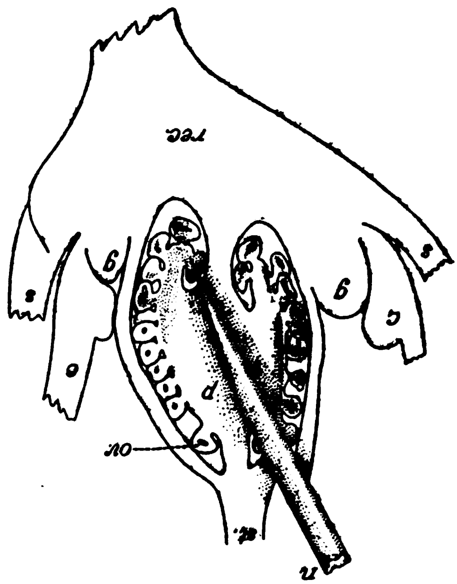

Fig. 4.—Longitudinal section of the basal portion of the flower of *Scrophularia*, to illustrate mechanical features of importance in ovarial treatments. The stippling shows the accumulations of methylene blue in the placenta and ovules. *c.*, corolla; *s.*, sepals; *g.*, nectar gland; *p.*, placenta; *st.*, style; *ov.*, ovule; *rec.*, receptacle; *n.*, tip of needle thrust through the ovarial wall and penetrating the placenta. (Drawn by F. E. Lloyd.)

(5) The changes produced are not premutational or cumulative, but are induced by direct physico-chemical action, and may be considered profitably without recourse to the conceptions of a complicated genetic terminology.

(6) A necessary preparation for the accurate use of this method consists in ascertaining the course of diffusion of the reagent, the time

and method of pollination, the rate of extension, and course of the pollen-tube, as well as the general structure of the ovule. (Fig. 4.) Duplication of results within narrow limits is not to be expected. An uncertain number of ovules are affected in any operation, the egg or sperm nucleus may be affected singly, or the fertilized egg may be reached by various concentrations of the reagent.

(7) The results of these experiments justify a consideration of the germ-plasm of plants as a concrete complex having two distinct phases, not as an "idealoplasm." In one phase it is the meristem or embryonic tract splitting off cells which pass into permanent tissues; the form and character of these differentiated cells may be greatly modified by environic forces, which, however, make no permanent impress on the germinal tract. The embryonic tract at times gives rise to specialized sexual reproductive elements, representing the second phase, during which process a halving of the number of chromosomes takes place. Subsequent to these reduction phenomena, the germ-cells may be profoundly influenced by extrinsic substances in the manner described above.

Relation of Root-habit to Soil Temperature, by W. A. Cannon.

Studies on the root-habits of perennials, which have been carried on at the Desert Laboratory, have revealed striking differences in root-development among species living in close proximity and apparently subject to similar environmental conditions. For example, *Prosopis velutina* has a root-system which may penetrate the soil deeply, while the roots of *Fouquieria splendens* and *Opuntia versicolor* and other cacti rarely, if ever, attain a depth exceeding 40 cm. On the other hand, it has been learned that the two species last named, under certain cultural conditions, may send their roots to a depth of a meter and more. A tentative explanation, based mainly on experimental studies of the leading causes which operate to bring about the results noted, will be offered in the succeeding paragraphs.

As already stated in another section of this report, the temperature response of desert perennials is unlike. For example, the temperature suitable for effective growth-rate of the roots of *Opuntia* and *Fouquieria* is relatively high and lies above 21.5° C., while the roots of *Prosopis* grow fairly actively at a temperature 5° C., or more, below this. It is thought that this unlike response to the temperature of the soil, taken together with the seasonal march of soil temperature at various depths, may be the chief causes which determine the type of root-development characteristic of the species.

An important feature of the soil temperature at a depth of 15 to 30 cm. is the great difference to be found in the amount of heat between winter and summer. This appears in an especially striking manner

when the soil temperatures are integrated. For example, the summation of soil temperatures, at a depth of 15 cm., for January 1910, and for July of the same year, holds the relation to each other of 1:7.

In the warmer months, July to September, the soil temperature at a depth of 15 cm. ranges between 21.5° and 27.0° C. during times of storms, and between 27.0° and 32.5° C. in fair weather. The soil is rapidly, and greatly, cooled by the summer rains, as is graphically indicated by figure 5, p. 95. At a depth of 30 cm. the summer temperature is somewhat less than at the lesser depth, and the daily fluctuations are relatively slight. At depths greater than 30 cm. these two features are accentuated.

During the colder months, from October to April, inclusive, the soil temperatures at 15 cm. and below are, with brief exceptions, under 21.5° C. and frequently attain to 10° C., and even less. The daily fluctuations at a depth of 30 cm., in winter as in summer, are less than at the lesser depth. Although but few measurements of temperature at a depth greater than 30 cm. have been made, it is known that it is less variable from day to day, and season to season, than at the more shallow depths, and also that at all times it is relatively low.

Such being an outline of the soil-temperature throughout the year, it appears, from what has been learned in regard to the response of the roots of the perennials to temperature, that the roots of *Prosopis* and of *Fouquieria* and *Opuntia* must needs take an unlike course in development. Probably at no time of the year is the temperature of the soil at the depth attained by the roots of *Prosopis* so low as to inhibit root-growth or (especially in spring, summer, and autumn) so low as to be unsuited to an effective rate of growth of the roots. Thus, low temperature is not, in the case of *Prosopis*, a limiting factor in root development. So far, on the other hand, as concerns *Fouquieria* and *Opuntia*, it appears that the soil temperatures, taken together with the impossibly dry condition of the upper soil in the arid fore-summer, sharply limit the period of root growth to the latter half of summer and September, and to other seasons, especially spring, when the upper soil is moistened by rains, and it is also so warm as to allow an effective growth-rate of the roots of these species. Thus, as regards the period of root growth in *Fouquieria* and *Opuntia*, low temperature is possibly the most important factor by which it is limited; and, as regards the development in the soil, the same factor is probably the definitive one, inasmuch as, within certain limits, the soil temperature falls with depth beneath the surface. For example, with temperatures at depths greater than 40 cm., too low to allow effective root growth, such growth is confined to the upper soil, and a superficial type of root-system results, such as characterizes *Fouquieria* and *Opuntia*.

The Direct Effect of Rainfall on Tropical Hygrophilous Vegetation, by Forrest Shreve.

A report has been prepared for publication of work carried out in the montane rain-forest of Jamaica, directed to an investigation of the possible physiological effects of prolonged wetness on the foliage of the thin-leaved plants of the rain-forest. The wetting of leaves was found to lessen the amount of their intake of water from the stems, and apparently also to lessen their transpiration. The lessening of intake was found not to be due to the cooling of the leaf, which is slight under rain-forest conditions of humidity, but to be due chiefly to the stoppage of the transpiration which normally takes place through the stomata-free upper surface of the leaves, and also partly to the intake of rain-water by the leaf-surface itself. The wetness of foliage serves, accordingly, to lessen the entry into the leaf of root-absorbed water, with its dissolved content of inorganic salts, and to increase the entry of rain-water, which is practically salt-free. The influence of such impoverishment of the intake of salts can not fail to be of great importance in connection with several of the fundamental processes that take place within the leaf, and it has been correlated with the slow rates of growth that have been shown to take place in the rain-forest.

The investigation of the dripping-point, or drip-tip, has shown that it is without functional value as a means of hastening the drying of foliage in the rain-forest. The growth of small liverworts, lichens, and mosses on the leaves of plants—a common and deleterious phenomenon—has been shown to be a function of the humidity conditions surrounding the plant rather than a function of the possession or absence of dripping-points. Hydathodes, or water-exuding pores, are of relatively infrequent occurrence in the Jamaican rain-forest, although the physical conditions are such as would give them the functional utility they have been supposed to possess. Cases of the complete injection of water into the parenchyma of leaves were observed in the rain-forest after exceptionally heavy rain, and the plants with hydathodes were found to be injected, although the prevention of this injurious condition has been alleged to be the chief function of these structures.

The Non-absorbing Atmometer, by B. E. Livingston and J. W. Shive.

The porous-cup atmometer (the only instrument so far available for adequate quantitative study of the aerial environment of organisms, so far as the water relation is concerned) has continued to attract attention. Mr. J. W. Shive, fellow in plant physiology in the Johns Hopkins University, has greatly improved the non-absorbing mounting for this instrument. It will be remembered that this mounting involves, essentially, an arrangement by which water moves readily from reservoir to evaporating surface, but not in the opposite direction.

Thus the non-absorbing instrument records practically all the evaporation occurring during the period of exposure and absorbs practically no water when the evaporating surface is externally covered by a water-film, as with rain or dew. The simple mercury valve of Professor Livingston's device has been retained, simplicity and certainty of operation being the main advantages of this form over any form of mechanical valve that might be constructed, but the arrangement of Mr. Shive places both filling and operating valves within the water reservoir, thus producing a self-contained instrument. This makes the non-absorbing form available for all kinds of field studies. The original absorbing form is still employed wherever it is certain that the evaporating surface will not be wetted from without.

Spherical Porous Cups for Atmometry, by B. E. Livingston.

Failure of the manufacturers to furnish an adequate supply of Professor Tower's porous spheres for atmometric use[1] has led to the repetition of an earlier attempt to procure suitable spheres in the United States. This attempt has resulted in very promising pieces and it is hoped that the required porous spheres, of one make or the other, may soon become available for general employment. The white sphere possesses no advantage over the white cylindrical cup; a vertical cylindrical evaporating surface seems fully as satisfactory as a spherical surface for measuring the evaporating power of the air. The need for spheres arises from quite another aspect of the general subject of atmometry, namely, from the desirability of measuring the effective intensity of radiant energy, as this influences evaporation from exposed water-imbibed surfaces. The radio-atmometer, devised for this purpose, comprises two otherwise similar evaporating surfaces, one of which is white, the other black. The white surface reflects most of the impinging radiant energy, while the black surface absorbs a considerable portion. The two surfaces, being similarly exposed, are similarly affected by the evaporating power of the air, and the difference between their evaporational losses is an approximate measure of the radiant energy absorbed by the black one during the period of exposure.

From the nature of the radio-atmometer it follows that the bundle of intercepted rays, from whatever direction, should always meet the evaporating surface at the same mean angle. Since the sun is the main source of radiant energy with which students of evaporation have to deal, and since the bundle of intercepted rays from this source is continually altering its direction throughout the day and from day to day, with reference to any point on the earth, it is clear that a spherical surface is the only possible one that will intercept the sun's rays always at the same mean angle and not require continuous or

[1]See Year Book of Carnegie Institution of Washington No. 12, page 71.

very frequent adjustment. Though the radio-atmometer has been operated with cylindrical cups, it was early recognized that the instrument could never be fully satisfactory for general field-work without spherical cups, both white and black. With these spheres the instrument should at once become of great value to climatologists as well as to biologists.

Atmometric Units, by B. E. Livingston and H. C. Sampson.

Another feature of atmometry requiring attention as the subject has advanced is the relation of various units by which evaporation may be measured. Although it seems to have been clearly and repeatedly shown in the literature that the rate of water-loss from any evaporating surface is as much a function of the nature of the atmometer as it is of the surrounding conditions, there is, nevertheless, a pronounced misapprehension on the part of many workers in this field, who appear to regard depth units of water-loss from "a free water-surface" as somehow the standard units in terms of which all other measurements should be expressed. From elementary physics it can be readily established that the ratio of water-loss from one atmometer to that from any other in the same surroundings can be constant throughout varying external conditions (such as those of wind, temperature, etc.) only when the two water-surfaces are exactly similar in all respects. If the surfaces differ but slightly, or if the external conditions (affecting both instruments alike) vary within only a narrow range, constancy of the ratio is of course more or less closely approximated. It follows that evaporation readings obtained by means of the porous-cup atmometer can never be expressed in terms of water-loss from a free surface, excepting for a *certain, special evaporation vessel* under a *certain, definite set of surrounding conditions.*

Mr. Homer C. Sampson, assistant in botany in the School of Education of the University of Chicago, has carried out, during the summer of 1914, a considerable series of evaporation measurements, under widely varying external conditions and with a variety of different sizes of evaporator pans and of porous clay cups, obtaining illustrative data bearing upon this important and little appreciated principle. In order that evaporation records may be comparable, they must all be obtained by means of similar instruments, but what particular form of instrument should be used must be determined mainly by convenience and by the kind of exposure of the natural evaporating surfaces with which the study deals. Thus, the porous-cup atmometer is better suited to plant-transpiration studies than is an instrument employing an open pan of water, because the evaporating surface of the cup is more like plant surfaces than is a free water surface, and also because the exposure of the cup is more like that of plants.

Relation between Atmospheric Conditions and Soil Moisture Content at Permanent Wilting of Plants, by B. E. Livingston and J. W. Shive.

The study of this relation, already advanced by the work, at the Desert Laboratory, of Dr. W. H. Brown (1909) and Dr. J. S. Caldwell (1910), was carried farther, also at the Desert Laboratory, in the summer of 1913, by Mr. Shive and Professor Livingston. The results showed, for several soil mixtures and several plant forms, that the moisture-content of the soil at permanent wilting of the plants increased approximately 0.5 per cent (on basis of dry-soil weight) for each doubling of the atmospheric evaporating power.

The Water-attracting Power of the Soil, as measured by the Rate of Loss from the Auto-irrigator, by B. E. Livingston and L. A. Hawkins.

The auto-irrigator is essentially like a porous-cup atmometer, the cup buried in the soil instead of being exposed to the air. Dr. L. A. Hawkins, of the U. S. Department of Agriculture, working with Professor Livingston at the Laboratory of Plant Physiology of the Johns Hopkins University, carried out a series of measurements upon potted plants irrigated automatically with this device. In such cultures the rate of water-loss from the irrigator is highest somewhat later in the day than occurs the maximum in the transpiration rate. The rate of loss from the irrigator then falls slowly, reaching its minimum in the early morning. It appears that this rate may be valuable in the dynamic study of soil-moisture conditions.

The Water-supplying Power of the Soil, by B. E. Livingston and H. E. Pulling.

As mentioned in the preceding report, Mr. H. E. Pulling, fellow in botany in the University of Wisconsin, working at the Desert Laboratory during the summer of 1913, measured the water-supplying power of several soil mixtures by means of cane-sugar osmometers with collodion membranes. This method, together with other possible methods for measuring the water-supplying power of the soil, promises to open the field of water relations between plant and soil, so that these may be quantitatively studied. Mr. Pulling is continuing these investigations at the University of Wisconsin.

The Transpiring Power of Plant Foliage, as measured by the Method of Standardized Hygrometric Paper, by B. E. Livingston and A. L. Bakke.

Mr. A. L. Bakke, instructor in plant physiology in Iowa State College, working with B. E. Livingston at the Desert Laboratory during the summer of 1913, obtained comparative measurements of this important and apparently characteristic internal feature for a large num-

ber of plants. This work clearly indicates that the index of foliar transpiring power is a criterion by which the xerophytism or drought resistance of plants (as far as their leaves are concerned) may be quantitatively approximated. The main results will appear in an article in the Journal of Ecology. Mr. Bakke has carried this study still farther during the summer of 1914, at the Desert Laboratory.

Permanent Standardization of Cobalt-chloride Paper for use in measuring the Transpiring Power of Plant Surfaces, by B. E. Livingston and Aleita Hopping.

Further study of the conditions determining the time required for the color change of hygrometric paper over the standard water-supplying surface, carried out by Miss Aleita Hopping, at the Laboratory of Plant Physiology of the Johns Hopkins University, has shown clearly that this time-period is determined, for a given sample of cobalt-chloride paper, by temperature alone, and that the length of this period is inversely proportional to the maximum vapor pressure of water corresponding to the given temperature. This point, which has long been suspected, makes it possible to omit from the field observations all reference to the standardizing water-test; simply the air temperature (or preferably that of the leaves) is to be recorded instead. Each slip of hygrometric paper is to be standardized in the laboratory, at a known temperature, and from this observed time-period is to be calculated the time-period required for color change by the same slip at any other temperature. A table of relations between temperature and length of time-period is readily prepared, thus reducing the calculation to a minimum for field-work. This advance removes the most troublesome features of the method and renders it much more readily adaptable to the needs of field ecology and agriculture than has been the case. Other improvements in the technique of the method have been accomplished which will be set forth in a journal article.

PHOTOLYSIS, RESPIRATION, HYDRATATION, AND GROWTH.

Periodic Variations of Respiratory Activity, by H. A. Spoehr.

The continuance of the study of the influence of light on living plants is revealing more and more the extreme complexity of these reactions. It is hoped, by means of a careful study of the chemical and physical reactions induced by light in the organisms and in vitro, that the explanation of physiological light reactions may be found, and that ultimately certain climatological effects may be interpreted on this basis. This analysis is revealing the fact that the quality of the light (wave-length and intensity) is of great importance for a thorough investigation of the subject, requiring a large amount of preliminary work in other fields.

Earlier experiments on the influence of sunlight and ultra-violet light on important plant processes had given indication that light acted not only directly by inducing chemical and physical changes of physiologically important substances within the organism, but also acted indirectly by affecting the air surrounding the plant. This latter effect is plainly noticeable in the respiratory activity. An extended series of experiments was carried out in which the only variable factor to which the plants were exposed was the air of the day on the one hand and that of the night on the other. A respiration apparatus was so arranged that air was drawn directly from out-of-doors, freed from the carbon dioxide by means of coarse soda-lime, then drawn over the plants kept in the dark at constant conditions of temperature and humidity, and finally through a standard barium-hydroxide solution in Meyer's tubes. Thus it was found that the rate at which carbon dioxide was evolved was regularly higher during the hours of day than during the night. As a working hypothesis, it was assumed that these differences in respiratory activity were due to variations in the chemical activity of the atmospheric oxygen, as indicated by the values for atmospheric ionization. Therefore the air was discharged by passing it between the opposite poles of a series of electric batteries before coming in contact with the plants. Thus the differences in respiratory activity between day and night were considerably reduced.

It was found that these variations in carbon-dioxide evolution were sufficiently great to give reliable results only when the material used is actively respiring, when the gaseous exchange with the atmosphere is not difficult, and when there is a sufficient supply of carbohydrate food material. For these and cultural reasons wheat seedlings proved most convenient. However, due to the relatively rapid rise and fall of their respiratory activity, a mathematical comparison between the day and night rates becomes difficult. Nevertheless, the course of the rate of carbon-dioxide evolution of successive 3-hour periods shows a marked similarity with the variations generally given for atmospheric ionization; while with the deionized air the rate of carbon-dioxide evolution rises and falls in an even curve. The following summarizes the experiments, which ran 12 to 15 days; the rate at which carbon dioxide was produced is taken from 12-hour periods:

Material.	$\frac{\text{Day rate.}}{\text{Night rate.}}$	
	For normal air.	For de-ionised air.
Onions	1.15	.....
Wheat seedlings	1.042	1.010
Wheat seedlings	1.091	1.014
Beetles	1.099	.....

Gas Interchange and Acidity in Cacti, by H. M. Richards.

The actual rate of carbon-dioxide evolution and oxygen absorption is governed by more than one factor. Primarily, as one might expect, the age and condition of the tissue exert a very considerable effect. The mature joints which are in the flaccid condition that characterizes them in the dry season show a relatively low rate of gas interchange, while the turgid mature joints are half again as active, and in the young joints (that are just forming and are in their most rapid growth phase) the rate is at least twice as great. But conditions may be present which entirely mask these differences.

Temperature, of course, is an active influence in determining the rate at which the gases are given out or taken up, as can be seen by the table on page 88, where the experiments are arranged in four temperature groups. In this tabulation, which represents the actual averages of most of the gas-interchange experiments that have been undertaken in this research, there are, indeed, a few discrepancies in this regard. Thus at 35° to 37° C., under the ratio of 0.51 to 0.60, the rate appears lower than at 31° to 34° C. This is simply because the number of experiments averaged in that case is small and they happened to be with relatively dormant material. The tabulation is exactly as the experiments happened to fall. Under the ratio 0.81 to 0.90, which represents the averages of the greatest number of experiments, there is seen to be a consistent rise in gas-interchange rate to somewhat more than double the initial rate, paralleling a rise in temperature of about 12.5° C.

Acidity is also a controlling factor, for while it is usually highest at the lower temperatures it also rises with the ratio, as is shown most strikingly in the column giving the cubic centimeters of acid per gram dry weight. It is evident from inspection of the table that high $\frac{CO_2}{O_2}$ ratios, high acidities, and high rate of gas interchange are all associated. It is indeed what would be anticipated and is in keeping with what has been announced in previous reports. When the acidity is high there is, other things being equal, a marked tendency for it to fall if the slightest stimulus which favors the breaking up of the acid is present, such as increase in illumination, prolonged darkness, or rising temperature. The splitting of the acid results in the great absorption of oxygen and the still greater formation of carbon dioxide. Thus the ratio rises and approaches or even exceeds unity. The actual rate of gas interchange which accompanies these disruption processes must naturally be greater than at periods when the acidity is low, for since the acid is the origin of at least a large part of the carbon dioxide formed, it is obvious that when there is less actual acid present there could not, under any circumstances, be so much carbon dioxide produced.

Taking a general average of all of the results except the single group at 40° to 41° C., we find that at one end the average ratio of 0.46 (with an evolution of carbon dioxide amounting to 0.88 c.c. per gram fresh weight per hour), while at the other end (with an average ratio of about 1.00) the amount has more than doubled. It is more satisfactory, however, to follow the rates and ratios of a single temperature group,

Tabulation and averages of ninety-six gas-interchange experiments, arranged according to $\frac{CO_2}{O_2}$ ratios.

$\frac{CO_2}{O_2}$ ratio.	Temperature.	Acidity, "pure juice" per cubic centimeter.	"Total acidity" per gram fresh weight.	"Total acidity" per gram dry weight.	Average $\frac{CO_2}{O_2}$ ratio.	CO_2 evolved per gram per hour.	O_2 absorbed per gram per hour.	No. of experiments averaged.
	° C.					c. c.	c. c.	
0.41 to 0.50	23 to 24	0.92	0.32	1.71	0.49	0.077	0.154	2
	28 30	0.50	0.23	1.17	0.43	.095	.223	6
	31 34	0.45	0.25	1.12	0.45	.076	.167	3
	35 37	0.34	0.22	0.91	0.48	.094	.195	5
	23 37	0.47	0.23	0.97	0.46	.086	.187	16
0.51 to 0.60	23 24	1.06	0.60	1.80	0.53	.075	.144	4
	28 30	0.31	0.22	0.98	0.55	.098	.175	3
	31 34	0.53	0.24	0.96	0.56	.118	.209	5
	35 37	0.50	0.22	0.65	0.59	.099	.169	1
	23 37	0.64	0.34	1.50	0.56	.107	.194	13
0.61 to 0.70	23 24	1.00	0.55	2.35	0.68	.096	.141	5
	28 30	0.54	0.32	2.34	0.64	.113	.179	5
	31 34	0.50	0.29	1.26	0.64	.155	.244	4
	35 37	0.78	0.68	3.68	0.66	.185	.280	3
	23 37	0.71	0.44	2.22	0.67	.110	.165	17
0.71 to 0.80	23 24	0.96	0.52	2.64	0.79	.119	.150	2
	28 30	....	....	....	....	....	....	..
	31 34	0.84	0.49	3.10	0.75	.195	.264	7
	35 37	0.89	0.50	2.35	0.75	.177	.236	6
	23 37	0.88	0.50	2.75	0.77	.201	.260	15
0.81 to 0.90	23 24	1.54	0.98	4.20	0.84	.131	.156	9
	28 30	1.24	0.79	4.83	0.86	.110	.130	3
	31 34	1.28	0.87	4.78	0.82	.206	.240	7
	35 37	1.26	0.83	3.98	0.90	.237	.263	3
	23 37	1.45	0.94	4.68	0.86	.177	.205	22
0.91+	23 24	2.32	1.38	5.75	1.00	.139	.139	4
	28 30	1.32	0.82	5.27	0.93	.171	.184	4
	31 34	1.38	0.87	2.72	0.90	.277	.299	1
	35 37	....	....	....	....	....	....	..
	40 41	1.20	0.60	2.60	1.22	.340	.303	4
	23 41	1.53	0.90	4.63	1.08	.285	.263	13

and in the table given that at 31° to 34° C. represents the largest number of experiments averaged and consequently is the most illustrative. There is a constant rise in the rate of gas interchange with the rise in the ratio, the difference between the highest and the lowest being more than 300 per cent. The other groups are also in accord.

With the increased evolution of carbon dioxide there is of course an accompanying increase in the absorption of oxygen which, however, must be less than the former, since the ratio is rising.

In this very brief analysis of the series of experiments represented by the accompanying table, some of the most striking points are brought out, but the discussion is of course incomplete. It may be safely said, however, that there can be no doubt of the association of high acidities which are falling with high rate of gas interchange and with rising $\frac{CO_2}{O_2}$ ratios, while low acidities which are rising are accompanied by low gas-interchange rate and lower ratios. Thus, as was said in last year's report, a young joint in which we may expect to find the highest acidities will have the highest ratio and most rapid intake of oxygen and output of carbon dioxide. Other things being equal, a flaccid joint with low acidity will average the lowest ratio and slowest evolution of carbon dioxide. It should be said, however, that in certain instances the lowest ratio has been found with young joints which are largely depleted of their acid.

The gas samples from all of the experiments undertaken during the summer of 1913 which touch upon the subject in hand have been analyzed and the results calculated out by Miss M. E. Latham, and all the other material which has accumulated since the writer began this work in 1911 has been assembled. While it is evident that there are several lines in which the problem must be investigated more fully and that there are several new lines of work which show promise, it is time that the mass of accumulated data be brought together in definite form, and that has been the work of the present summer.

Water-content and Acidity of Succulents, by E. R. Long.

The investigations on the diurnal variation in the acidity of cacti have been extended to the sahuaro (*Carnegiea*) and bisnaga (*Echinocactus*), with the additional object of discovering if the acidity of the outer layer differs from that of the inner, and if the light and temperature effects upon the acid are different in the two regions. At the end of a hot day as much as 15° C. difference may be observed between the exterior and interior regions of a bisnaga 25 cm. in diameter.

It developed that there was a decided difference between the acidity values of the expressed juice from different regions of the same plant, the acidity for a given tract in the cool of the early morning being

almost directly proportional to the relative dry weight of the tissue tract, while in the late afternoon the acidity throughout the plant diminished, the decrease being considerably greater in the outer layers than in the inner, as would be expected from the higher temperature and light intensity acting upon the former. The water-content of both the sahuaros and the bisnagas averaged about 95 per cent in the central tissues and 90 per cent in the outer regions. The acidity of the sahuaro is somewhat higher than that of the bisnaga, while the sap of both is much lower in acid-content than that of the opuntias.

A method is being developed to obviate certain difficulties encountered in the usual method of determining acidity in the expressed juice, chief of which are the slimy product obtained by the latter method and the rapid action of the oxidases on injury to the tissue, both of which render titration difficult, and also to make possible the determination of the acid present in small quantities of material, as 1 to 5 grams of moist tissue. The essential feature is alcoholic extraction, the subsequent titration being made with phenolphthalein, as usual.

Growth and the Hydratation of Colloids in Cacti, by E. R. Long.

In view of the suggestion of a number of investigators, especially Borowikov and M. Fischer, that conditions which effect an increased hydratation of plant colloids, notably the presence of acids, cause increased growth of the plant, attempts have been made to correlate the growth of succulents with their varying acidity, which has been described in the reports of this department for 1911, 1912, and 1913, by Dr. Richards and Dr. Spoehr. It was thought at first that the common observation of a higher rate of plant growth at night might be accounted for by the increased acid-content of the plant-sap during this period. However, early in the course of these experiments Dr. MacDougal observed that the highest growth rate of *Opuntia blakeana* takes place during the day, *i. e.*, in the period of decreasing acidity, and experiments were made to determine whether the phenomenon noted here might be an effect of the varying acidity of the plant-sap.

It was immediately found, by placing pieces of *O. blakeana* in various solutions, that the swelling induced in dilute acids was decidedly *less* than that occurring in distilled water. It seems highly improbable that this was an osmotic-pressure effect, in view of the fact that, in a solution of a neutral salt, *e. g.*, potassium nitrate, of the same molecular strength as the acid, the swelling was much greater than in the acid solution and fully as great as that taking place in distilled water.

Experiments on the growth-rate of cacti paralleled the experiments on swelling. The growth of (1) developing flowers and (2) of new joints of *O. blakeana* and *O. discata* was distinctly less when the parent joint was absorbing N/100 and N/50 hydrochloric and malic acids

than when the parent joint was absorbing distilled water. These were the concentrations of acid used in the swelling experiments and are much lower than the concentration within the plant, which in the species used varies approximately between N/10 and N/20. In solutions of neutral salts of strength equimolar with that of the acid used, the growth-rate lay between the acid and distilled-water extremes.

A final experiment showed that the swelling power of the same joint was much greater at 5 p. m. (period of lowest acidity) than at 5 a. m. (period of highest acidity), the difference between the acidity values at the two times being greater than could be accounted for by the osmotic-pressure variance due to the day's transpiration.

From these experiments it seems that there is a parallelism between growth and colloid hydratation, and that acidity, instead of being a favoring factor, is, at least in the plants used, inhibitive to both.

Further experiments showed that dilute alkalies induced a somewhat greater hydratation than distilled water. The interesting fact developed that in nutrient solution—containing K_3PO_4, $MgSO_4$, KNO_3, NaCl, and $Ca(NO_3)_2$—not only was there an increased growth-rate of cacti over that in distilled water, but also the hydratation of isolated pieces was greater—that is, that the greater growth-rate and hydratation took place where the difference in osmotic pressure was smaller. The field of salt action in colloid hydratation entered here is undoubtedly an enormous one.

Relation of the Rate of the Growth of Roots to Soil Temperature, by W. A. Cannon.

Studies on the response of the roots of desert perennials to different soil temperatures have been carried on by means of especially devised apparatus, by which the growth of the roots can be observed and the cultures can be kept at any desired temperature for any desired period. As a general result of these studies, it has been learned that representative perennials, such as *Prosopis velutina*, *Fouquieria splendens*, and *Opuntia versicolor*, exhibit characteristic responses to parallel temperatures, and that such responses may be unlike. As examples of such reactions, the following measurements on root growth can be given:

During 42 days of spring (April–May) the roots of the species which were growing in glass tubes and at air temperatures increased in length as follows: *Opuntia*, 341 mm.; *Prosopis*, 309 mm. In 13 days in April the root of *Fouquieria* grew 117 mm., and those of *Prosopis* and *Opuntia* 181 and 162 mm., respectively. The temperature of the soil was 26° C., and over. For a period of 24 days in November–December, the root of *Prosopis* increased 315 mm. in length, that of *Fouquieria* 136 mm., and that of *Opuntia* 89 mm. The soil temperature ranged from 12.3° C. to 21.3° C., which is the average of readings made at

7^h30^m a. m. and 6 p. m. The following table is a summary of the maximum and minimum amounts of growth (in millimeters) for any day (24 hours) during the course of the two experiments:

Plant.	April–May.		November–December.	
	Max.	Min.	Max.	Min.
Prosopis.......	24	2	17	3
Fouquieria.....	10	0	7.5	1
Opuntia.......	20	2	5	1

Other experiments by which the same individuals were subjected to varying temperatures for equal periods gave essentially the same results. They also showed in a more exact manner the root response to different temperatures. The root of seedling *Prosopis*, for example, increases the rate of growth with rise in the temperature of the soil, between 15° and 40° C., in a fairly consistent way. It approximately doubles its growth-rate with each rise of 10° C. The temperature of largest response varies with the experiences of the individual, being higher at the first trials (when youngest) than at subsequent trials (when the root has elongated), although there may intervene only one day between trials, and the entire duration of the experiment may occupy only 5 days. (See table below.)

Average growth for 2-hour periods of 4 specimens of Prosopis at temperatures given.		Average growth-rates of 4 specimens of Fouquieria at intervals of 2 hours at the temperatures given.	
Temp.	Growth.	Temp.	Growth.
° C.	*mm.*	*° C.*	*mm.*
21.5	1.7	18.0	0.4
28.0	3.9	29.0	1.1
36.0	4.8	35.5	1.4
41.5	3.6	39.0	0.9

Similar studies on the relation of root-growth to soil-temperature show that the growth-rate of *Fouquieria* roots is not so rapid as in *Prosopis* at the same temperature, and especially that growth at relatively low temperature in *Fouquieria* proceeds with great slowness. (See above table.)

Figure 5 gives the integration of a thermograph air-record covering the duration of the experiment, together with the dates of the experiment. The short interpolated curve is the integration of a thermograph record made in the root cage between November 24 and 30, when artificial heating was employed.

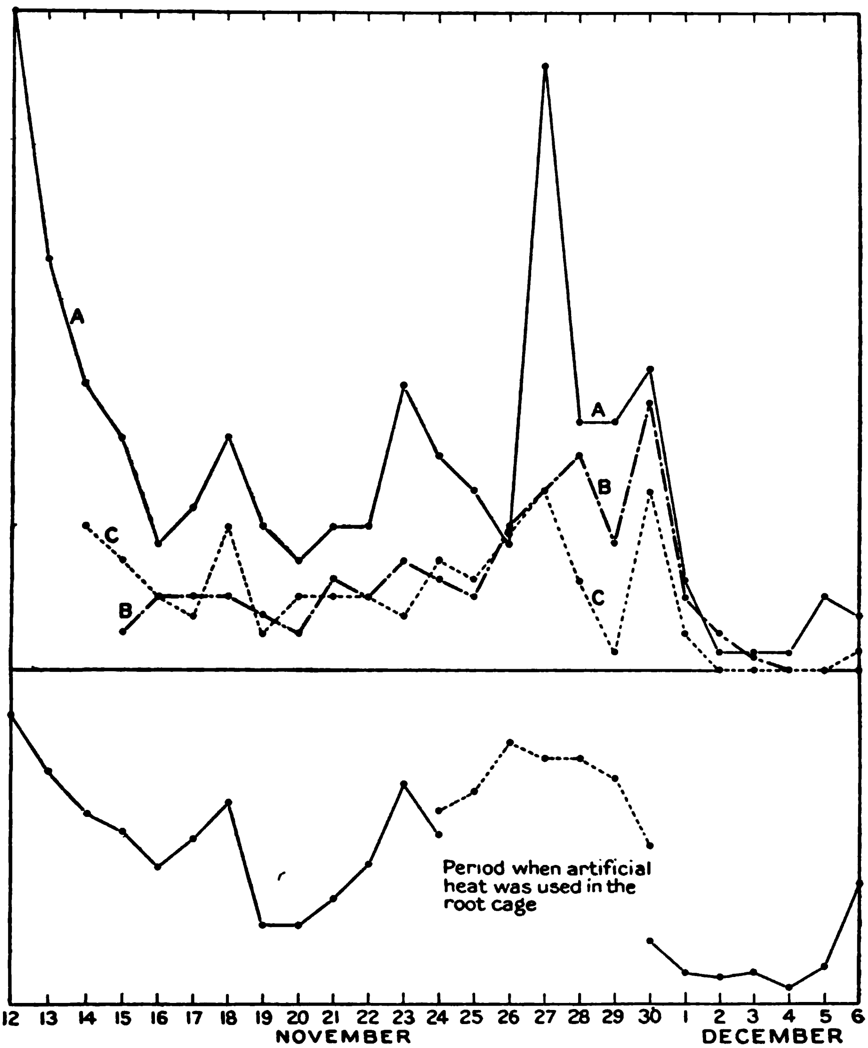

Fig. 5.—Daily growth of the roots of desert perennials. The growth of *Prosopis velutina* is indicated by the continuous line (A), and that of *Fouquieria splendens* (B) and *Opuntia versicolor* (C) by broken lines, –.–.– and ......, respectively. Scale: 2.5 mm. ordinate equals 0.5 mm. growth.

The differences in rate of growth at the same temperature appears in a striking fashion in the following summary of one experiment in which both *Prosopis* and *Fouquieria* were growing in the same tube. The interval is 12 hours.

Plant.	14.5° C.	26.5° C.	31° C.
	mm.	*mm.*	*mm.*
Prosopis.......	6	24.0	27.0
Fouquieria.....	4	8.5	11.6

The temperature response of *Opuntia versicolor* is similar to that of *Fouquieria*, at least for temperatures around 30° C. For example, in one instance, at temperature ranging between 13.5° and 21.5° C., growth of 0.5 mm. in 24 hours was observed, and in another instance the growth was 2.5 mm. at the same temperature. With increase in temperature, the growth-rate of the roots is accelerated, so that, for instance, at 30° C. the growth in 24 hours was 12.8 mm., at 31° C. it was 18.6 mm., and when the temperature was dropped to the earlier low position the total growth for 24 hours fell to 3.5 mm.

As a contrast to the temperature relation (as just given) of *Opuntia versicolor* from the Tucson region, it is of interest to note that of *Opuntia* sp. from an island in the Susquehanna River, where the natural temperature relations are necessarily quite different from those of the former region. When given temperature ranging between 13.5° and 21.5° C. for 24 hours, the Susquehanna cactus grew 8.4 mm. At 4-hour periods, and at the temperature of the soil named, the roots of this *Opuntia* made the following growths: at 25° C., 2.1 mm.; at 34° C., 2.4 mm.; at 38° C., 4.3 mm.; at 39° C., 2.7 mm.

Methods used in Studying the Response of Roots to the Temperature of the Soil, by W. A. Cannon.

In the investigations on the relation of root-growth to the temperature of the soil, two general methods have been employed. In the one case, root-boxes have been used having one side of glass, sloping at an appropriate angle, so that the growing roots should come into contact with the glass, and the direction as well as the rate of their growth could be easily observed. In a special form of root chamber a differential temperature effect was obtained by heating one end and cooling the other.

The second type of apparatus was one in which the temperature is controlled automatically by a regulating device. This form consists of several separate thermostats, built of metal and insulated, and so arranged that the roots which are growing in glass tubes containing soil are kept at any desired temperature for an indefinite time. In

such apparatus the shoots are exposed to the temperature of the air, or, if desirable, the entire apparatus can be placed in a glass cage whose temperature can also be controlled independently of the root thermostat. In order to expose the cultures to different temperatures, the glass tubes are changed from one thermostat of a certain temperature to another of a different temperature.

By the use of the root thermostats described, the effects on root-growth of factors other than temperature, or in addition to temperature, can also be observed. For example, the effect of various gases and of variation in aeration of the soil, as well as the effect of different kinds of soil and differences in soil-moisture, can be studied and measured. The method, in short, is found suitable for the study of the activities of roots in a great variety of ways, and in a manner which places the plants observed under relatively small departures from the normal.

Temperature, Transpiration, and Water-Content of Leaves, by Edith B. Shreve.

Since August 1913, an investigation of the water relations of some of the typical desert plants has been carried on, with a view to determining the behavior of (1) the same species at different seasons and of (2) different species of annuals at the seasons in which they grow. The plants now under investigation are as follows: two perennials, *Parkinsonia microphylla* and *Encelia farinosa;* a winter annual, *Streptanthus arizonica;* a summer annual, *Amaranthus palmeri;* and also a plant which can be grown in the green-house at any season, *Phaseolus* sp. At intervals of 2 to 4 hours measurements have been made of transpiration, leaf and stem water-content, leaf temperature, and stomatal openings. Samples of leaves have been preserved for anatomical study, and records of air temperature, humidity, evaporation from the porous-cup atmometer, and of soil water-content have been kept during the experiments.

Thus far the data have not been worked over sufficiently to warrant the statement of any conclusions, but a few facts have appeared, as follows: (1) The variability of the water-content of the foliage from different branches and from different plants, taken at the same time, must be found experimentally before conclusions can be drawn regarding the hourly variation of leaf water-content of any species; (2) no adequate comparison of leaf water-content, transpiration, stomatal openings, or leaf temperature can be made unless all the plants used have had the same history in regard to approximate age, soil water-content, and general atmospheric conditions; (3) a variation in the water relations takes place with the seasons; (4) incipient drying has appeared in the xerophytic forms, under conditions of high evaporation; (5) leaf temperature goes above air temperature, in sunlight, in the case of leaves of the xerophytic type, and remains below air tem-

perature, under the same conditions, in leaves of the mesophytic type; (5) leaf water-content varies as much as 100 per cent from winter to summer in a single species and varies considerably with the soil water-content at any one season.

The calorimetric method for the determination of leaf temperature has been improved by the use of a more accurate means of finding the specific heat of the leaves. A known amount of heat is introduced into the calorimeter by means of a mercury calorifer, and arrangements for the calibration of this instrument have been made with the Bureau of Standards. A check on the constants of the calorimeter will thus be provided.

Autonomic Movements of Stems of Opuntia versicolor, by Edith B. Shreve.

Work has been continued on the movements of *Opuntia* stems, which has been reported upon in previous years. Dr. MacDougal suggested that the large variations in amount of acid in this plant, which have been found by Dr. H. M. Richards, might affect the water-holding capacity of the colloids and thus set up the motion. Plants were placed under controlled conditions, where an increase or decrease of acidity could be predicted,[1] and their movements were measured. The tests were conducted under (1) constant high temperature and varying light conditions; (2) constant low temperature and varying light conditions; and (3) constant darkness and varying temperatures. With certain exceptions, later satisfactorily accounted for, a downward motion or curvature was always accompanied by an increase in acidity and an upward motion by a decrease in acidity.

As noted in the Year Book for 1913 (p. 79), the seasonal position has been shown to be a function of the turgidity, depending in turn upon the soil water-content. This has been confirmed by application to potted plants, where the branches can be made to straighten or curve by changing the amount of water in the soil. The statement made last year, that the upward motion takes place only in direct sunlight, has been found to be wrong, as a more careful measurement and at shorter intervals showed that the rate is very much retarded but not stopped in diffuse light or in darkness, and under some conditions the decrease in rate is not very great.

Transpiration studies were continued with the same results as before, namely, a higher relative rate occurs at night than in the day time if a moderate amount of water is present in the soil, and a higher actual transpiration rate occurs at night if the soil water-content is high. Plants were cut and allowed to develop roots in water and then used for the measurement of water intake and outgo. It was found, under conditions of average transpiration, such as occur in the greenhouse in summer, that the water intake at night is less than the outgo,

[1]Dr. H. A. Spoehr kindly aided in the prediction of the acidity conditions.

while during the day the intake is greater than or at least equal to the outgo. When the movements of a plant were measured simultaneously with the water intake and outgo, it was found that the upward motion in the day is accompanied by an increase in the amount of water in the plant and that a downward motion at night is accompanied by a decrease in the amount of water in the plant. If the plants were placed under excessive evaporation conditions in the day time, a slight upward motion occurred, but was followed by a large downward motion, while at the same time a decrease in the water left in the plant occurred. The night following such a day always showed an increase in water-content and a rise of the stem. So that, without exception, when intake is greater than outgo the stems rise or straighten and when intake is less than outgo the stems fall or curve.

An examination of the water-content of stems from plants in the open and from the green-house showed that the highest water-content is at 5 p. m. after the close of a bright day, and the lowest just before daylight the next morning, with an intermediate amount at noon.

Small cylinders of equal dimensions were cut from the center and from the outer cortex of stems, and their water-absorbing capacity was tested by immersion in distilled water, the gain in weight per gram of dry weight being determined by weighing at definite intervals. The original water-content and the dry weight of these same pieces were also determined. Acidity determinations were made of similar pieces taken at the same time of day, the amount of acid being expressed in terms of the equivalent cubic centimeters of N/50 NaOH required to neutralize the acid in one gram of water in one gram of dry weight. The results show that, at all times of day and night, both water-content and absorbing capacity are greater in the outer than in the central part, and that the acidity of the center is always greater than that of the outer cortex. The absorbing capacity and water-content of the entire stem are greater at 5 p. m. than at 5 a. m. and the acidity is higher at the morning hour. The absorbing capacity and water-content increase more during the day for the outer than for the inner region. This constitutes a second line of evidence that the greater the acidity the less the absorbing capacity of the material.

Thus at least a partial explanation of the cause of the movement is found in the varying water-content of the stems, which is caused by a varying absorbing capacity of the plant material. The greater transpiration rate at night is also explained by the same phenomenon. The chain of events is somewhat as follows: At night the absorbing capacity of the tissues becomes less and they therefore more easily give up for transpiration the water which they contain; at the same time they have a lessened ability to take up the water, to replace that given off by transpiration, and thus the water-content of the plant becomes less at night. During the day the absorbing capacity increases,

and the plant in turn resists the pull from the air, cutting down the transpiration rate, while at the same time it has an increased ability to take up water to replace the amount lost. The increased water-content of the tissues coincident with minimum acidity is in harmony with the results of Mr. E. R. Long, who found that the hydratation of tissues of cacti was less in dilute acids than in distilled water (see p. 92). This result is also in agreement with the measurements of growth by Dr. MacDougal (not yet published), which show maximum rate of enlargement at the time of least acidity. It does not conform, however, to the conclusion of Fischer, Borowikov, and others on the influence of low acidities on hydratation.

The measurements of water-content and absorbing capacity show a slight tendency toward a movement of the water within the stem from the center toward the periphery during the day, and a return toward the center at night, thus making an outer supporting cylinder of turgid cells during the day, which would tend to the erection of stems, but would probably not be great enough to be the sole cause of the movement. It is also probable, from experimental evidence, that the rise is further aided by the increase in turgidity caused by the absorption of heat energy from direct sunlight. But evidence from exceptions to the usual behavior points to the changes in water-content as being the most important cause of the motion.

VARIOUS SPECIAL INVESTIGATIONS.

Fruit Development in the Cactaceæ, by Duncan S. Johnson.

The continuation of experimental work on *Opuntia fulgida* shows that detached fruits, when placed on damp soil in the green-house or laboratory, give rise to roots 5 cm. long in 5 weeks' time. No shoots were evident at this time on these fruits. Shoots planted in a green-house had shoots 3 cm. long after a year's growth. While flowers arise, on the attached fruits, only from areolæ near the top, vegetative shoots may arise, on detached fruits, from areolæ at the base, middle, or top, depending on the position of the fruits in the soil. Roots may arise from any areola placed downward in the soil or may even develop independently of an areola on the margin of the perianth scar at the top of the fruit or close to the scar of the broken off fruit-stalk at its base. That is, a root may evidently arise at any point on the fruit where it can push through the epidermis. Data are being gathered to aid in determining the cause of the persistent adherence of the fruits of this cholla and of the cause of its final dislodgment.

A study of the development of the fruit, seed, and embryo sac of *O. leptocaulis* is being made for the sake of comparison with the cholla and as a basis for experimental work on this species at Tucson. In most of the features mentioned, *O. leptocaulis* shows rather close simi-

larity to the other species. The fruits of *O. leptocaulis*, like those of the cholla, are often sterile. More than half of them contain only small shriveled rudiments of seeds. The fruits of this species do not remain attached as long as those of *O. fulgida*, though some of them may stick to the parent plant for a year after they are mature.

When freed from the plant, the fruits of *O. leptocaulis* root promptly and apparently may give rise to new plants as readily as those of *O. fulgida* do.

Fruits and the peculiar deciduous joints of *O. leptocaulis*, when placed on damp soil in a cool laboratory, developed roots 3 cm. long in 5 weeks (in July) and the new shoots on the same joints were then 2 cm. long. External examination and sections showed that roots may arise from the margin of any areola of the buried part of the fruit or joint. In other cases a root may arise from the center of the scar of the broken-off stalk of the joint and from a direct continuation of the axis of the latter, with the vascular bundles of the two intimately connected.

The deciduous joints above mentioned are formed in dozens on the tips of the long shoots of this slender-stemmed *Opuntia*. These joints are 6 or 7 mm. in diameter, from 2 to 5 cm. long, and are arranged on the long shoots like the fruits, among which they frequently appear. The general appearance and number of areolæ on the shorter of these shoots, together with their arrangement, suggest that they may really be regarded as phylogenetically derived from sterile fruits. It is expected that examination of a large number of specimens will determine whether there exist structures intermediate in character between these propagula and the sterile fruits that are readily recognizable as such. The development of 4 or 5 flowers, from the more terminal areolæ of certain of these propagula which remain attached to the plant, is perhaps what should be expected if they are regarded as purely vegetative branches. The form of the persistent propagulum, however, with the grouping of the flowers at its tip, gives quite the appearance of a flower-bearing fruit of *O. fulgida*.

Morphological Studies of Carnegiea gigantea, by C. E. Bessey.

Structural studies were made of the flower-buds and flowers of the sahuaro, and photographs were obtained of the latter when fully open. These were produced upon a branch 1 meter long, sent from the Desert Laboratory to the plant-houses of the department of botany of the University of Nebraska. The development of the buds was followed day by day until they opened (in the forenoon), reached their maximum (about midday), and then slowly closed (by nightfall). In the new habitat the branch produced four sets of flowers, three in May and one in September. Repeated attempts to secure fruits by artificial pollination failed. Advantage was taken of the opportunity afforded

by these flowers of determining the number of stamens and ovules which they contain by making actual counts of both, resulting in finding 3,482 stamens and 1,980 ovules in one flower.

The sahuaro was studied especially with reference to the cortical ridges and the ribs of the fibro-vascular framework showing a numerical correspondence. Both increase in number upward, so that they are found to branch ascending the stem. The study of the method of branching is still in progress. Externally the cortical ridges are somewhat closer together on the southerly half of the stem than on the northerly half, and the same is true with reference to the fibro-vascular ribs of the internal framework. The average of many measurements showed that the ridges (and ribs) on the northerly and southerly sides were numerically as 9 to 10½.

In cross-section each fibro-vascular rib is ovate in outline, with the smaller curve looking inward in the stem, the larger looking outward. There are no visible growth-rings in the ribs, although they increase in radial diameter. They show distinct medullary rays. Their more detailed histology is still under investigation.

Some Studies of Fouquieria splendens, by C. E. Bessey.

Structural studies of this shrub were begun at the Desert Laboratory, and continued at Lincoln, Nebraska. These included the flowers and seeds, including germinations of the latter, and the growth of the young seedling. These studies tend to confirm the suggestion that *Fouquieria* should be taken from the order Caryophyllales, and included rather in the order Ebenales, near the families Symplocaceæ and Styracaceæ. Studies have been begun upon the structure of the cortex of the mature stems, especially to the translucent layers overlying the chlorophyll-bearing tissue of the cortex.

Plant Succession, an Analysis of the Development of Vegetation, by Frederic E. Clements.

The summers of 1913 and 1914 have been spent chiefly in testing in the field the conclusions as to the development of vegetation which have been reached during the last decade in the study of Rocky Mountain vegetation. The basic principles involved have been definitely formulated during the past year, and an endeavor has been made to summarize and correlate all of the literature which deals directly with plant successions, amounting approximately to 500 titles. The vegetation scrutinized during the two summers extends from the Great Plains to the Pacific Coast and from the Canadian Rockies to the Mexican boundary. The climax formations of this region have been traversed repeatedly, and their variations and interrelations have been critically compared. An attempt has also been made to coordinate the detailed

results of European investigations and to interpret them in the light of recent advances.

The concept is advanced that the climax community typical of each climatic region is the result of a definite organic development, and hence is a basic unit of vegetation, *i. e.*, a formation. This has furnished a new basis for the analysis of vegetation, and makes available a natural method for the classification of the plant communities of the world. It also makes it possible to interpret all the structures of vegetation in terms of successional development, and to discover in existing vegetation organic relationships which have hitherto been obscure or unknown. A striking advance has been made in correlating vegetation and climate, and this promises to throw a flood of light upon the relations of climate and vegetation in the geological past. Progress has been made to a stage in which it is possible to sketch the climax formations of the various geological periods and to relate them in a developmental series.

An exhaustive analysis has been made of the initial, ecesic, and stabilizing causes of unit successions, and especial attention has been given to the orientation of topographic, climatic, and biotic processes. As a result, it has been possible to extend and refine our present knowledge of the structure of vegetation and to propose a purely developmental classification of plant communities. Out of this has come a new conception of the interrelations of contiguous climax formations and their correlation with past and future climates.

The Relationships and Distribution of the Cactaceæ, by N. L. Britton and J. N. Rose.

Field-work in this investigation was continued by Dr. Britton in Porto Rico and islands adjacent in February and March, including successful exploration of the small islands Desecheo and Mona, in the Mona Passage between Porto Rico and Santo Domingo, and the cacti of both these islands were collected and transmitted to Washington and to the New York Botanical Garden; one of the most interesting results was the recognition of the long-lost *Cactus moniliformis* of Linnæus. Important knowledge on the distribution of species was also obtained. Dr. J. A. Shafer explored the island of Vieques, on behalf of the New York Botanical Garden, and obtained specimens of the cacti of that island. At the end of May, Dr. Britton again visited Bermuda and studied cacti in cultivation there. The collection of cacti made by Mr. John G. Sinclair during the winter in Colombia, South America, supplied valuable information concerning the species of that region. The explorations of Dr. MacDougal in Arizona, California, and Nevada during the year added much to our knowledge of species and their distribution. Additional information and specimens concerning the cacti of Panama were received from Mr. H. Pittier.

On June 10, Dr. Rose sailed from New York on a tour of four or five months to study the cacti of western South America. This is the most important field-work yet undertaken in the United States for the study of cacti. The family is represented nearly throughout South America, extending into Patagonia, and there are perhaps as many species existing in South America as in all North America south to the Isthmus of Panama and including the West Indies. The majority of these plants are very little known, and it is probable that many exist which have never yet been studied or collected by botanists. The successful carrying out of this exploration will therefore be sure to contribute greatly to the scientific knowledge of the family. In July, Dr. Rose commenced shipping collections from Peru and reported very satisfactory progress. We are indebted to W. R. Grace & Co. and to the Central and South American Telegraph Company for valued cooperation and assistance in this work.

The preparation of manuscript and of illustrations for the volumes planned to present the results of this research has proceeded continuously, except while the investigators have been in the field, and much progress has been made. The descriptive accounts of most of the genera and of the majority of the North American species, including those of Central America and the West Indies, have been drawn up. Genera which are represented in both North and South America are as yet incompletely elaborated, but the field-work of Dr. Rose this year in western South America and another trip planned for 1915 in eastern South America should supply the material to complete the investigation essentially.

DEPARTMENT OF ECONOMICS AND SOCIOLOGY.*

HENRY W. FARNAM, CHAIRMAN.

Steady progress has been made in the work of most of the divisions during the past year, and the early history of transportation, running to about 1850 and prepared under the direction of Professor B. H. Meyer, is practically completed and can soon be submitted to the Institution for publication. In the case of several other divisions the time required for revision, verification, and preparation for the press has been longer than was anticipated. Professor Commons, however, hopes that his history of the labor movement will be finished in the winter, and the same may be said of the history of commerce in charge of Professor Johnson. Dr. Clark resumed work for the department on September 1, 1913, after an almost complete interruption since April 1909. He occupies a room in the Administration Building, at Washington, and has been steadily at work on his history of manufactures since last autumn. He hopes to have the first volume completed before the close of the calendar year. Professor Willcox has taken a leave of absence for half of the academic year in order to devote himself intensively to the subject of Population and has made good progress, though he will probably require another year to complete the work. Similarly Mr. E. W. Parker has obtained permission from the Director of the Geological Survey to devote half of his time from January to July of the present year to his work under this Department. He is now at work upon the history of mining, using as a basis for part of his volume the extended monographs on separate parts of the subject already prepared under his direction. The writer has continued uninterruptedly his study of social legislation, but has found it impossible to complete it in all its details.

In the Division of Agriculture, several of the sections report material progress during the year. Professor Blackmar has collected a good amount of material bearing on the history of agriculture prior to 1825, and Professor Taylor's study of agricultural prices from 1840 to 1860 is well advanced. Professor Hibbard and Professor Jones are also at work on the subjects of land tenure and markets, respectively. In this, as in some other divisions, the limits of time and available funds make it impossible to treat the subject with absolute completeness, but important sections should be finished within a year or two. Professor Dewey, after considerable interruption through ill health, has resumed work on the history of banking, and Professor Gardner is securing additional monographic material on the subject of public finance. For the reasons explained in earlier reports, the study of the Negro

*Address, Yale University, New Haven, Connecticut. (For previous reports see Year Books Nos. 3–12.)

problem, under Mr. A. H. Stone, and that of industrial organization, under Professor J. W. Jenks, are suspended for the present, but these gentlemen hope to resume their work later. The Index of State Documents for New Jersey is in press, and the manuscript of the volume for Pennsylvania is completed. Considerable work has been done on South Carolina, which is the next State to be taken up.

In view of the appointment of the chairman of this Department as Roosevelt professor at the University of Berlin for the winter semester 1914–1915, Professor Walter F. Willcox was elected acting chairman, at a meeting of the collaborators held May 23, and the books were turned over to him in July. The war necessitated, however, the canceling of the Berlin engagement, and the chairman returned to the United States in September. He has now resumed charge of the work of this Department, and hopes to give most of his time to it during the winter.

DEPARTMENT OF EMBRYOLOGY.*

FRANKLIN P. MALL, DIRECTOR.

The second year of the work on embryological research has been continued along the lines laid down in the report on embryology as given in the Year Book for 1913. Only towards the summer of 1914 was the staff increased by the appointment of two additional research associates as well as several members of the technical staff. The eminent embryologist, Professor Franz Keibel, director of the Anatomical Institute at Strassburg, was appointed Research Associate on April 1. The plan was that he would cooperate with us in continuing the work as expressed in the Manual of Human Embryology, and arrangements had been made for a conference with him at Heidelberg on August 2. The European war, however, prevented this meeting, and, of course, no report can be expected from him at this time; nevertheless, our plans have been worked out with such detail through correspondence that for the present we can go on working independently.

During the year we were fortunate in securing the services of Dr. George L. Streeter, professor of anatomy at the University of Michigan, who is well known in connection with his studies on the development of the nervous system. Professor Streeter will continue this work under favorable conditions with us at Baltimore. He received the appointment of Research Associate on July 1.

A year ago many inquiries were made among leading anthropologists for a suitable investigator, preferably an anthropologist, to make a biometric study and measurements of our human embryos and fœtuses. On the recommendation of Professor Schlaginhaufen, of Zürich, one of his students, Dr. Michael Reicher, also a pupil of Professor Martin, was appointed our collaborator on February 1. Dr. Reicher undertook his task with great enthusiasm, and during a period of six months made standard anthropological measurements of the body and head of most of our fœtuses and of many of the embryos. He has also measured a large number of specimens in other collections. The first part of Dr. Reicher's work is partially completed, but as he was beginning to arrange it for publication, the war in Europe made it necessary for him to return to Russia. He has left all of his data with us and, as soon as he is released from military duty, will return to complete the task he has undertaken.

On April 1 C. H. Miller was appointed technical assistant, and on June 1 O. O. Heard, a skilled pattern-maker, was selected as modeler.

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*Address: Johns Hopkins Medical School, Baltimore, Maryland. (For previous report see Year Book No. 12.)

The collection of human embryos has been greatly increased, largely as the result of a circular, written by Professor Herbert M. Evans, which was widely distributed. Many printed history blanks and directions to physicians regarding embryological material were also sent out, thus enabling us to secure better histories of well-preserved specimens. An extensive correspondence with physicians in the Orient has brought us two specimens from China and a few dozen from the Philippines. We have also secured a very young embryo from an American Indian. A preliminary study of these specimens, as well as those from negroes, show that racial characteristics become apparent much earlier than we had anticipated.

The collection is well housed and catalogued. By means of the card catalogue, which has been begun, it is quite easy to use it as a reference collection. A list of the specimens arranged according to their age and their accession is given in the following table:

Table giving the number of normal and pathological specimens, arranged according to their age in months, collected each year since 1887.

Year.	1 month (0–2½ mm).		2 months (3–25 mm).		3 months (26–68 mm).		4 months (69–121 mm).		5 months (122–167 mm).		6 months (168–210 mm).		7–10 mos. (211–336 mm).		Total speci-mens.
	N.	P.	N.	P.	N.	P.	N.	P.	N.	P.	N.	P.	N.	P.	
1887	.....	.....	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1
1888	.....	.....	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1
1889	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1890	.....	1	1	.....	2	.....	1	.....	1	.....	.....	1	.....	1	7
1891	1	1	5	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	7
1892	1	.....	3	1	4	.....	.....	.....	.....	.....	.....	.....	.....	.....	9
1893	3	1	1	.....	.....	.....	1	.....	1	.....	.....	.....	.....	.....	7
1894	6	1	3	.....	1	.....	.....	.....	.....	.....	1	.....	1	.....	12
1895	.....	1	4	1	4	.....	2	.....	.....	.....	.....	2	.....	2	14
1896	3	3	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	7
1897	5	8	17	7	10	1	4	.....	5	.....	.....	.....	.....	.....	57
1898	.....	2	8	4	.....	2	3	.....	1	.....	1	.....	.....	.....	21
1899	.....	5	7	6	6	1	2	.....	1	.....	.....	.....	.....	.....	28
1900	.....	4	3	3	6	2	.....	.....	1	.....	.....	.....	.....	.....	19
1901	.....	4	4	5	3	.....	.....	.....	.....	.....	.....	.....	.....	.....	16
1902	.....	1	3	4	5	1	.....	.....	.....	.....	.....	.....	.....	.....	14
1903	.....	2	3	3	4	.....	1	.....	1	.....	.....	.....	.....	.....	14
1904	4	6	11	11	13	1	2	.....	.....	.....	2	.....	1	.....	50
1905	.....	9	6	11	7	4	7	2	.....	.....	.....	.....	.....	.....	46
1906	1	7	18	21	7	.....	3	.....	2	.....	5	.....	2	.....	64
1907	2	6	18	7	3	.....	3	.....	1	.....	.....	.....	.....	.....	40
1908	.....	6	9	2	5	.....	3	.....	.....	.....	.....	.....	.....	.....	25
1909	.....	.....	2	4	2	.....	1	.....	.....	.....	.....	.....	.....	.....	9
1910	.....	.....	.....	2	10	4	3	.....	2	1	.....	.....	.....	.....	22
1911	.....	25	20	14	16	.....	6	2	4	.....	2	1	1	1	90
1912	5	17	11	7	13	.....	4	1	2	.....	1	2	.....	2	63
1913	9	50	30	37	41	5	21	3	.....	9	.....	5	.....	2	210
	40	160	190	150	162	21	67	8	22	10	12	11	5	8	853

Among the abortions during the first month only one-fifth of the specimens contain normal embryos; from those in the second month over one-half, and in the third and fourth months eight-ninths of the embryos are normal. Beyond this the table is of little value for statistical purposes, as a very large number of normal fœtuses obtained by physicians are not sent to us. A study of the membranes shows that many of those encircling embryos, although normal on first appearance, are diseased, thus accounting for the abortion. The cause of this diseased condition is undoubtedly a previous venereal infection or in some cases perhaps a puerperal infection associated with a former childbirth. (See Mall, Journal of Morphology, vol. 19, 1908.)

The study of pathological embryos has been continued and all that bear catalogue numbers from 400 to 500 have been prepared for microscopic examination. This work will have to be continued slowly for a number of years before a final comprehensive report can be made. Meanwhile the results obtained from an examination of 117 specimens of tubal pregnancy should be published during the coming winter.

The statistical study of the normal form has been undertaken by Franklin P. Mall and by Michael Reicher. The latter has completed about 12,000 anthropological measurements on 385 specimens as a basis of an exact study of the growth of the body and its proportions; the data concern chiefly the fœtuses from the beginning of the ninth week until birth. In each instance 23 standard anthropological measurements of the head and 20 of the body were taken. About one-third of the material for his study was placed at Dr. Reicher's disposal by the Anatomical Departments of the University of Minnesota, the University of Chicago, and the University of Michigan. For this kindly cooperation we are indebted to Professors C. M. Jackson, R. R. Bensley, G. W. Bartelmez, and G. C. Huber.

A preliminary report on the study of the form, classification, and age of embryos less than 25 millimeters long has been made by Franklin P. Mall. It is quite apparent why it is difficult to determine in a satisfactory way the age of human embryos; the time of fertilization is practically impossible to ascertain, as we do not know with certainty when ovulation takes place, and even if this were known it would still remain to be determined how soon after ovulation the sperm-cell enters the egg. Of course, we know in a general way that conception probably begins near a menstrual period, but here again there is a difference of opinion of nearly a month, as it is uncertain whether we should count from the last period or from the first lapsed period.

The evidence which bears upon this subject has been brought together in Chapter VIII of the Manual of Human Embryology, edited by Keibel and Mall. In order to compare the obtainable data, it was necessary to consider anew the question of measuring human embryos.

The material and data at our disposal are by no means entirely satisfactory, inasmuch as the records in the literature are not always carefully given, and those found among the records of various collections are subject to considerable variation, owing to inaccuracy and lack of uniformity in making measurements, not to speak of the shrinkage of the specimens in the fluids in which they have been preserved. Thus the measurement was often made after the specimen had shrunken greatly or was determined after the embryo had been cut into serial sections. Hence it can readily be understood why measurements of the small preserved specimens sometimes fall short of those of the fresh specimens by fully 50 per cent. Thus, an 8-millimeter embryo may shrink to 4 millimeters, which, according to the curve of growth given by Mall, would belong to a 33-days-old pregnancy, whereas, according to the convention of His, it would be 21 days old. In all probability a specimen that, when fresh, measures 8 millimeters is nearer 40 days old. Here there is a discrepancy of three weeks to be accounted for.

In measuring young human embryos it must be emphasized again that the crown-rump measurement, or sitting height, should be made from the crown, over the middle of the mid-brain, to the lowest point of the rump while the embryo is fresh, or, what amounts to the same thing, after it has been fixed in formalin. This measurement should be exact, as it represents the living and not the shrunken embryo.

In recent years we have measured a large number of embryos, first, fresh or in formalin, and again after dehydration; finally they will be measured in paraffin. Nevertheless, if all the suitable specimens in the literature are compared with the best in our collection, the variation in size at a given stage is still very pronounced. In order to give the question a test, we photographed all of the good profile illustrations given in the literature, so that the pictures of the embryos gave a crown-rump measurement of about 50 millimeters. Then we had prints, enlarged to this size, made from our own negatives. These various photographs could now be compared from different standpoints—that is, they could be arranged according to their menstrual age, according to their greatest length, or according to their degree of development. When the photographs were arranged according to their menstrual age, no satisfactory classification could be reached. When considered according to size the results were no better. Finally, when grouped according to their stage of development, a more satisfactory result was obtained.

At first we arranged the 266 photographs of embryos, ranging from 2 to 25 millimeters, in 20 stages, taking the external features (branchial arches, arms, and legs) as our guide. Since all of the photographs had been marked arbitrarily to conceal the length of the specimens, and as there were numerous duplicates in the collection to confuse us, we continued arranging the photographs until the stages became thor-

oughly fixed—that is, until a misplaced photograph could be replaced in its group with ease and until all the duplicates fell together. At first some of these duplicates fell two stages apart, showing that not all the stages fixed at first were reliable. Finally, when the arrangement had been rendered as satisfactory as possible, we found that 14 stages remained, 6 having been eliminated. This arrangement is given in the accompanying table, in which photographs from illustrations in the literature, photographs of embryos in other collections, and those from our own collection are blended. When there are photographs of both sides of an embryo they are counted as one.

Table classifying 266 human embryos from 2 to 25 millimeters long arranged in 14 stages of variations in length (CR) and the number of specimens for each stage.

Stage.	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	
2 mm	3		1												
3 mm		2	3												
4 mm		2	6	4	3										
5 mm		1	1	3	9										
6 mm		2	1	3	5	5									
7 mm					8	7									
8 mm					1	19	2	1							
9 mm					1	7	6	3	1						
10 mm						2	9	6							
11 mm						1	3	1	3						
12 mm						1	1	1	1						
13 mm								6	4	2					
14 mm								4	9	1	7	1			
15 mm									6	1	1				
16 mm									3		8	1	1		
17 mm								1	2	1	5	2			
18 mm									1	2	9	1			
19 mm											2	3	1	1	
20 mm										1	3	6	3		
21 mm										1	1	1	5		
22 mm												2	6		
23 mm												1	1	2	
24 mm												2	2		
25 mm												1	1	2	
Total	3	7	12	10	27	42	21	23	30	9	36	21	20	5	=266

The various stages have been arbitrarily marked with letters of the alphabet, beginning with H, reserving the letters A to G for younger stages like that of Bryce and Teacher. When the mean measurements are taken it is found that Stage H is 2 millimeters long, the embryo increasing a millimeter in length for each stage from H to L and 2 millimeters from L to U.

The gap between stages over 25 millimeters long and those measured by Dr. Reicher is yet to be filled in, but the material is at hand for this work and many new data which have been secured will enable us to construct a new and more satisfactory curve of growth for all stages of development.

To establish stages of development and the probable age of the embryos of each stage is one of the difficulties encountered in the study of abnormal development. In an attempt to do this it is necessary to consider the development of the corpus luteum, and much material towards this study has been secured. Incidentally a specimen of true ovarian pregnancy was found located within the cavity of the corpus luteum. This is described in a publication by Franklin P. Mall and Ernest K. Cullen.

The work of Warren H. Lewis and that of Herbert M. Evans, on the anatomy of embryos, mentioned in Year Book No. 12, has been continued during the past year, and it is planned to prepare them for publication during the coming year. That of Professor Lewis includes the development of the skull and muscles of the head in embryos up to 25 millimeters long, whereas that of Professor Evans considers mainly the anatomy of embryos between 2 and 4 millimeters long, together with the surface anatomy of older stages. The work of George W. Corner on the development of the pancreatic duct and the structural unit and growth of the pancreas has been published during the past winter.

The observation of Eleanor Linton Clark and Eliot R. Clark on the movements of the lymph heart in the living chick embryos are of interest in connection with the discovery that the muscle of the lymph heart is derived from the myotomes. They observed that the early movements of the lymph hearts are always associated with movements of the body and tail and that the lymph-heart beat is gradually dissociated from other movements.

A study of the development of the azygos veins has been carried on by Professor Sabin, who finds that the azygos veins are not remnants of the posterior cardinal vein, as has hitherto been thought, but that they are entirely new veins that develop for the drainage of the prevertebral tissues, and their increase in size is a consequence of their taking over the intercostal veins. This study opens up the larger problem of the relation of the great veins of the adult to the primitive veins of the embryo, and indicates that it is the vena cava that replaces the posterior cardinal vein and not the azygos veins. Only a preliminary report of this study has been published.

The study of Lewis H. Weed on the medulla, by means of reconstruction, has been brought to a conclusion, a summary having been published in the Anatomical Record, the completed paper appearing as Publication No. 191 of the Carnegie Institution of Washington. In this work an attempt has been made to secure a more detailed account of the gray matter of the human medulla, partly in order to assist in following its development. This latter work has been carried on by Professor George L. Streeter and Dr. Charles R. Essick for a number of years and Dr. Weed's contribution will be of especial value to them.

In the work of Dr. Weed the individual interpretation of the many nuclear masses has, as far as possible, been eliminated from his reconstruction. Most of the collections of nerve-cells have been delimited under low magnification, with later substantiation of their limits under higher powers. It has been felt that probably more correct ideas of the nuclear masses are given by their characteristic appearance under slight enlargement than by the identification of the limits of the area in which the characteristic nerve-cells of the nucleus can be made out. Comparison of the findings by these two methods has shown the variation to be very slight.

In this reconstruction all the morphological characteristics of the various nuclei have been preserved as long as the preservation was technically possible. This more intimate anatomy of the nuclei varies undoubtedly in different brain-stems, but it has been thought of value to present this finer morphology of one brain-stem, as it is only by this means that the ultimate conception of the morphology of the nervous system can be advanced. The grosser form of each nuclear mass is, however, probably identical in all cerebro-spinal axes.

Different nuclear masses have been modeled on the two sides of this reconstruction. The left side shows only the individual collections of nerve-cells which go to form the well-defined nuclei. The anterior motor column is also modeled on this side, clearly cut away from the central gray matter by the decussatio pyramidum. On this side, too, the nuclei underlying the fourth ventricle are given in their relations to each other. In contrast to this dissected left side of the model is the more solid and less open right side. Here an attempt has been made to show morphologically the transition of the indifferent gray matter about the central canal of the spinal cord into the formatio reticularis of the medulla. The external form of the formatio has been modeled on this side, as has also the floor of the fourth ventricle. This presentation on the one side of the surface markings of the ventricular floor and on the other of the various nuclei which have surface representations permits accurate comparison of the ventricular anatomy with the underlying nuclear structure.

In addition to the above grosser studies in development we have directed our attention towards the structure and properties of the cell and the development of individual tissues.

The work of Professor Herbert M. Evans, on the behavior of the somatic cells toward vital stains of the benzidine group, will have an important bearing on cell classification and on our problems of histogenesis. Professor Evans has received several grants from the Rockefeller Institute and during the last year has published a considerable body of his data. In collaboration with Werner Schulemann he examined several hundred dyes of known chemical constitution as regards their biological behavior. These were all combinations of benzidine

or similar bases with the sulphonic acids of naphthols, amido-naphthols and naphthylamines. The study has proven that the distribution of these substances in the body and their anchorage in certain cells does not depend on any precise chemical configuration of the dye molecule, but rather on the physical state of their solutions. This generalization would appear to be significant for other fields of inquiry, pharmacology for example. The cells which are affected by these dyes are characterized by their power to absorb rapidly ultramicroscopic particles, whose physical dimensions fall within certain limits. Inasmuch as these cells are the great phagocytes of the body, and as there is no difference in their behavior toward particles of successively large size until ordinary microscopic dimensions are reached, we must consider that the act of phagocytosis, now known to be effective through surface-tension phenomena, operates in the case of the submicrons of certain colloids.

The cells which react in this way include the endothelium in five localities, viz, in the lymph glands, hemolymph glands, liver, bone-marrow, and spleen. This should be known as a specific endothelium. Its behavior is shared with the cells of the great serous cavities and the wandering cells (clasmatocytes) of the connective tissues. These cells must now be included under one great class. The fibroblastic cells of the connective tissue react to a distinctly lesser extent, their behavior toward the vital stain being sufficiently characteristic to clearly separate them. It is of importance that the ordinary blood elements do not react in this way. Dr. Evans has taken advantage of this fact to identify the rôle of cells concerned in the experimental production of various acute new growths of tissue, studied in collaboration with F. B. Bowman, Milton C. Winternitz, Roger P. Batchelor, and Katharine J. Scott.

Other cytoplasmic peculiarities of cell types have been investigated by Dr. Edmund V. Cowdry, who has examined the mitochondria of resting and dividing cells and demonstrated an elective vital staining of mitochondria in fresh blood-cells.

The cytological studies of Professor Eliot R. Clark, of which a preliminary publication has been made, have additional importance on account of their bearing upon the problem of the histogenesis of the lymphatic system. He has observed distinct nuclear differences in endothelial and mesenchyme cells of chick embryos of the fifth to the eighth day, differences expressed by tinctorial and morphological details of the nucleoli.

The nuclei of lymphatic and blood-vessel endothelium have either a single nucleolus or a pair of nucleoli, which are definite discoid bodies, sharply marked out from the remainder of the nuclear material with clear-cut, rounded outlines. The single nucleolus varies much in shape, according to the shape of the nucleus. These nucleoli have a distinctly reddish color. The remainder of the nucleus has a rather pale, fairly homogeneous granular appearance. The nucleus of the blood-capillary is slightly smaller than that of the lymphatic and nearly always has two nucleoli. The single nucleolus appears to be more common in the

nuclei of new-forming sprouts. Frequent mitotic figures may be seen in the endothelium of early lymphatics.

The nucleus of the mesenchyme differs in all the particulars mentioned. It contains two or more nucleoli which are not sharply differentiated from the remainder of the chromatin material of the nucleus, but which extend out into prongs and threads, and it does not have a characteristic shape. It stains distinctly bluish. The remainder of the nucleus has a slightly darker appearance and often contains small clumps of chromatin material.

The fact that the nucleus of the lymphatic endothelium possesses distinct morphological characteristics different from those of the mesenchyme cells in chick embryos, and that these characteristics are present in the earliest recognizable stages of lymphatic development, coupled with the fact that the nuclei of blood-vessels, with which the lymphatics are connected, have quite similar characteristics, furnish important evidence that the lymphatic endothelium is derived from the veins.

Our investigations concerning the development of the lymphatic system have been under way for several years and center about the work of Professor Florence R. Sabin. The purpose of her investigations has been to determine the morphology of the system as a basis on which to work out its development and its relation to other systems. Her study began with the discovery of centrally placed jugular sacs, which lie on the veins and constitute the first lymphatics. This discovery reversed the theory accepted at that time, namely, that the lymphatics began in the periphery and grew centrally. Starting, then, on the theory that the lymphatics develop from sacs, which in turn arise from veins, it was shown that they gradually grow outward and invade the body. This gradual invasion of the body involves, therefore, the study of the development of the entire system up to the adult stage. The principles of the development have been established, but the details have been only in part worked out. The next crucial point in this study was that relating to the nature of the growing lymphatic tips. That the growth of the lymphatic tip is by an extension of its own endothelium was demonstrated by the method of injection and observation of sections as far as was possible by those methods. The demonstration was put on an incontrovertible basis by Professor Eliot R. Clark, by observations on the growth of the lymphatic tips in the living tadpole's tail, in which he showed that new lymphatics invariably arise through growth from preexisting lymphatics. The next step in the chain of proof we owe to the work of Eleanor Linton Clark, who discovered, in the living chick, the blood of the vein backing into the first lymphatic buds, thus showing that the first lymphatic buds communicate constantly with the veins and therefore must arise from them.

Thus it has been shown that the lymphatics arise from the veins, grow by sprouting, and gradually spread over the body.

DEPARTMENT OF EXPERIMENTAL EVOLUTION.*

C. B. DAVENPORT, DIRECTOR.

Among the principal advances of the year have been the demonstration of the fact that the sex-behavior of pigeons can be altered by injections of extracts of the germ glands; the first proof that an apparently pure race may really be "heterozygous" (*i. e.*, mixed) in one sex; and clear evidence that marked aberrations may be associated with a detectable chemical differentiation of the cell-sap, and that development of the egg-embryo is accompanied by important demonstrable changes in chemical constitution at different stages. The exact method of inheritance of depressions that lead to suicide, and the sex-limited nature of inheritance in certain types of nomadism and alcoholism in man have been worked out, a useful hypothesis of the origin of plural determiners secured, a first insight gained into the evolution of the chromosomal complex (continuing work started at Columbia University, under Dr. E. B. Wilson), and further experimental evidence obtained of the reality of the selective nature of elimination.

STAFF.

The Director continued his work on heredity in poultry, sheep, goats, and cats and brought the work on canaries to a close. His major work has been the study of data obtained by the aid of the Eugenics Record Office. From July 17 to October 20 he was absent on a journey to Australasia on the invitation of the Government of New Zealand (as one of an American party of about 12) and of the British Association for the Advancement of Science. He gave public lectures on the work of the Station and on heredity at Auckland, Wellington, and Christchurch, New Zealand, and examined some of the results of the sheep-breeding experiments at Canterbury, especially the so-called "half-breds" and "Corriedales." He also inspected one of the flocks of Leghorn fowls that has an average yield of over 200 eggs per hen. Conferences were held with sheep-breeders, biologists, and government officials on matters of genetics and an effort is to be made to establish a chair in genetics in the University of New Zealand. At the Sydney (Australia) meeting of the British Association he read a paper on "Heredity of Emotional Traits," and later he gave a public lecture at the rooms of the Royal Society on "Heredity and Eugenics." He also made some observations on the aboriginal Australian, both "full blood" and "half caste," at Brewarrina.

Dr. G. H. Shull has passed the entire year at Berlin in order to complete the Burbank manuscript. He carried on experimental work at the greenhouses of Prof. Dr. E. Baur of the Landwirthschaftliche

*Situated at Cold Spring Harbor, Long Island, Nem York. (For previous reports see Year Books Nos. 3–12.)

Hochschule. During the summer Mr. H. H. M. Bowman made detailed observations on Dr. Shull's cultures at Cold Spring Harbor. Dr. J. A. Harris spent two months with Mr. Lawrence, assistant, at the Desert Laboratory, Tucson, Arizona, applying the methods of determining osmotic pressure of vegetable saps from the depression of the freezing-point as developed by Dr. Gortner and himself.

Dr. R. A. Gortner cooperated with Dr. Harris and Dr. Banta and continued his exceedingly interesting work on the chemical changes that accompany individual development. Dr. Gortner received an excellent offer of an associate professorship at the University of Minnesota, and the Laboratory has sustained a severe loss in his departure. During the five years of his connection with this Station he issued 37 contributions from the laboratory of which he had charge and advanced greatly our knowledge of the chemistry of animal pigments, the processes of pigmentation, and individual development.

Dr. A. M. Banta continued his studies on cave organisms and explored, for material, certain caves of Indiana and, in early October 1914, the caves of the Schoharie and Cobleskill Valleys in Central New York, known as Howe's Cave, Ball's Cave, and Becker's Cave. Dr. G. C. Bassett, who was a guest of the Laboratory from July 1913 and later was temporarily appointed to continue his work on the effect of alcoholism in rats, has received a call to the University of Pittsburgh. His work will be continued by Dr. E. C. MacDowell.

In accordance with plans matured last year Dr. Oscar Riddle transferred the Whitman collection of pigeons and the new stock to this Station in November and he began work here December 1, and his assistant, Miss Spohn, on January 1. His work is to complete the editing of the Whitman manuscripts for publication. Incidentally he is continuing certain researches that are necessary for the full treatment of one of the subjects upon which the late Professor C. O. Whitman had begun work. Mr. Charles W. Metz has been appointed to act as cytologist and is making studies on the behavior of chromosomes (the germ-plasm of Weismann) in the vinegar flies, *Drosophila*—a genus which assumes particular importance because of its use for experimental breeding by Professor T. H. Morgan, of Columbia University, and his pupils.

REPORTS ON INVESTIGATIONS IN PROGRESS.

SEX.

Studies on sex still constitute an important part of the year's work, although Dr. Blakeslee and Dr. Goodale are no longer with us and Dr. Shull's work has, during his absence in Germany, been directed into other lines. The chief work on this subject is that of Dr. Riddle.

Sexual Differentiation of Pigeon's Eggs, Oscar Riddle.

Over a year ago Dr. Riddle showed that, in pigeons, which usually lay two eggs at a time, commonly one male and one female, eggs destined

to produce males are smaller, and have higher water-content and smaller energy-content, than those that produce females. This conclusion he has repeatedly confirmed at this Station. Especially has he been able, by the use of the bomb calorimeter, to demonstrate that eggs destined to become males contain less stored energy than eggs destined to develop into females. Whether the difference in energy-content (however it may have arisen) is the cause of the difference in the eventual sex or whether it is induced by a certain difference in the unfertilized egg which determines the difference in storage metabolism is uncertain. There is reason for thinking that the ova of birds are of two kinds, those destined to produce males and those destined to produce females, and there is also evidence that the former contain a sex chromosome which the latter lacks. This difference in the chromosomal content of the eggs destined to be males and females, respectively, may therefore be the cause of the difference of energy-content of the two kinds of eggs. This is a matter for further study.

With the aim of determining whether a modification of the amount of yolk stored in the egg can control the sex of the resultant chick, Dr. Riddle has spent some time (partly in collaboration with Dr. Bassett) in trying to induce such a modification. One result secured is that when the female pigeon is subjected to alcohol vapor it lays smaller eggs than normal. Other substances used (phloridzin and urotropin) have caused a reduction in the fertility of the egg, but have not markedly altered its size.

The foregoing studies are of interest because of their relation to a normal determination of sex in the egg-laying of pigeons. If, as Whitman first pointed out, certain somewhat distantly related species of pigeons be crossed and if the eggs be taken away as fast as laid, so as to induce the pair to continue to lay fertile eggs, then in the beginning of the season (*i. e.*, in the spring) both eggs of a clutch will produce nearly or quite exclusively males; the last eggs laid in the autumn will be nearly or quite exclusively females; while in the transition period the first egg of the clutch usually produces a male and the second a female. Of course, one can not say that the experiment has induced any change in the sex-fate of the eggs; it may possibly be that the distribution of the male and female eggs in the ovary is such that this result necessarily follows from the forced heavy reproduction of the mother. Dr. Riddle holds an alternative hypothesis, and an attempt will be made to decide between them.

Modification of Sex Behavior in Pigeons, Oscar Riddle.

A very remarkable fact, in addition to those stated in the preceding paragraph, is that when two full sisters from such series are hatched from the two eggs of a single clutch the first hatched behaves in copulation as though it were a male. Also females hatched early in the season (the period when most males are produced) are more masculine

in behavior than are their own sisters hatched late in the season. Dr. Riddle has succeeded in some cases in reversing the sex-behavior. Thus, if extracts from the ovary of a pigeon be injected into those females that are behaving like males they come to behave like females. Contrariwise, if testicular extract be injected into those females that are acting like females they come to act like males. The full significance of this result is still obscure. The sex-behavior of a bird is probably determined by internal secretions from its sex-glands carried to its central nervous system. On this hypothesis the quality of the internal secretions of the ovaries of birds that act like males must be different from those of birds that act like females. The effect of the injected extract may perhaps be regarded as superior to that induced by the natural secretion of the ovaries.

Sex-linked Inheritance in Lychnis, G. H. Shull.

The series of studies on *Lychnis*, which exhibits certain characteristics that render it critical for the study, has been continued by the use of a narrow-leafed mutant that depends upon a sex-limited defect. The original narrow-leafed plant was a male which when crossed with broad-leafed females produced broad-leafed males and broad-leafed females; but when these were bred together they produced (in F_2) broad-leafed and narrow-leafed progeny. The narrow-leafed progeny were all males, but the broad-leafed progeny were partly males, partly females. Thus the narrow-leafed condition shows itself in F_2 only in males, though half of the females carry the determiner of narrowness in half of their eggs, as experiment proved. All of these broad-leafed F_2 females were crossed with the narrow-leafed males, and it was expected that in F_3 many narrow-leafed females would appear from the union of sperms carrying both the female character and the determiner for narrowness with eggs of the same constitution. It was an unexpected and baffling result that practically no narrow-leafed females occurred. This unexpected failure to produce narrow-leafed females in the F_3 was experimentally shown to be due to the absence or inefficiency in the narrow-leafed males of sperms carrying the determiner for femaleness, for crosses between these same narrow-leafed males and homozygous broad-leafed females resulted likewise in only a rare production of females. There is a theoretical reason for believing that the mutation first occurred in a male-bearing sperm and that a large section of the species (if not all of it) is characterized by sperms defective in regard to the broad-leaf determiner. Such defect could appear *somatically* only after an *egg* had also lost its determiner for broad-leaf, as the narrow-leaf is a recessive character. In support of this conclusion, a broad-leafed male and a broad-leafed hermaphrodite, both from points in the United States far from the home of the original mutant, were tested and were found to be heterozygous for the defect; that is, they

carried the defect in their germ-cells, but had never been able to reveal it up to that time in their progeny because all of the female germ-cells previously fertilized by their pollen had carried the determiner for broad-leaf. The fact that an hermaphrodite crossed with a heterozygous female exhibited this defect in its offspring completely confirms Dr. Shull's conclusion that his hermaphrodite mutants in this species were originated through a mutational change in the *males*. This important experiment supports the view, suggested long ago by de Vries, that many heterozygous individuals may carry a defect in their germ-plasm, even as a racial character, and this character may never express itself in the progeny because it has never got into the germ-cells of the opposite sex. In this paper a much-needed revision of sex-formulæ is undertaken which, it is hoped, may simplify and standardize current usage.

VARIATION.

The problem of variation of organisms still remains unanalyzed and little progress had been made in its treatment. At this Station this summer (1914) we have made a systematic search for striking variations in the field, we have studied the relation of variations in a plant to their position on the plant, and we have compared the chemical composition of varying organs or plants to learn how far the chemical differences that accompany morphological variations can be detected. Finally, we have made a beginning on the task of inducing hereditary variations at will—that is, altering the germ-plasm.

Mutations in Nature, H. H. M. Bowman.

During July and August 1914, Mr. Howard H. M. Bowman was assigned to the work of looking for striking and probably inheritable variations in plants near the Laboratory, with the aim of locating material that might be used for future studies in variation. In this search he was successful, since he recorded such variations, mutations, and aberrations in 66 species. He also recorded the condition of each leaflet for 393 seedling *Fraxinus* (ash) of known pedigree from ascidiate (pitcher-leafed) and non-ascidiate ancestry. The results will be used in Dr. Shull's study of this remarkable mutation.

Periodicity in Abnormality in the Passion Flower, J. A. Harris.

In *Passiflora* (the passion flower) the fruit shows a great number of abnormalities, mostly proliferation and allied phenomena. A comparison of the number of abnormalities in plants grown in normal soil and in soil to which a considerable proportion of bone-meal had been added showed no difference in the proportion of abnormal fruits, but established the fact that the proportion of abnormalities in the fruits

of any plant decreases as the plant becomes older. A similar periodicity has been described in other species, but usually in such cases the proportion of abnormal fruits *increases* with the age of the plant. The interpretation of the result is still uncertain.

Chemical and Morphological Differences, J. A. Harris and R. A. Gortner.

Dr. Harris and Dr. Gortner have undertaken studies on chemical differences associated with those of a morphological character. It appears that in a species (*Lagerstrœmia indica*) with dimorphic anthers, the larger red anthers lose water more rapidly upon evaporation than the slightly smaller yellow ones, a correlation that has a certain ecological bearing. Attempts were made to detect a chemical difference in the juices of apples and pears of varying size and fertility; the conclusion reached is:

"We have, however, been unable to demonstrate any sensible differences in the osmotic pressure, mean molecular weight, or electric conductance of the saps of nearly ripe fruits of different sizes or producing different numbers of seeds. However, between the tissues of the normal capillary whorl constituting the wall of the fruit of *Passiflora gracilis* and those of the *tetramerous, abnormal whorl* forming the teratological mass, *i. e.*, the secondary fruit sometimes found within the otherwise normal fruit, there is unquestionably a *differentiation in physico-chemical properties of the expressed juices*, as follows: The specific gravity, specific electrical conductivity, osmotic pressure, and ratio of the electrical conductivity to the depression of the freezing-point are distinctly *higher* in the saps extracted from the tissues of the wall than in that expressed from the abnormal mass. Thus the *electrolytes form a relatively smaller and the non-electrolytes a relatively larger proportion of the solutes in the sap of the teratological tissue.* Apparently the mean molecular weight of the solutes of the sap of the included mass is higher than that of those extracted from the wall."

These matters are discussed in detail in a paper now ready for the press. To facilitate the calculation of molecular weights and osmotic pressure in saps from observed depression of the freezing-point, Doctors Harris and Gortner prepared for publication two extensive tables.

Modification of the Germ-plasm by Alcohol, G. C. Bassett.

The problem of inducing changes in the germ-plasm has been attacked by subjecting organisms to the action of alcohol vapor. This is a method which Stockard has already employed with success in demonstrating that after having been subjected to the vapor of alcohol the capacity of germ-cells for producing viable offspring diminished. Dr. Bassett has sought to find if any inheritable effect of such alcoholization of a parent upon intelligence of its offspring might be detected. Unfortunately, after having elaborated the method with great care, he was obliged to abandon the experiment. Its continuation is now in the hands of Dr. MacDowell.

Abnormalities in Development Resulting from Centrifuging Eggs, A. M. Banta and R. A. Gortner.

As a by-product of some chemical studies, interesting abnormalities in developing embryos of frogs were induced which are worth recording, though they have no obvious significance for heredity. Dr. Banta and Dr. Gortner "centrifuged" some embryos of *Rana sylvatica* at the blastopore stage, subjecting them to 1,350 times the pressure of gravity for 2 minutes, and an accessory tail-like appendage developed in all of the survivors—usually one accessory tail, but occasionally two to four. The accessory tails were scattered along the mid-ventral region and had a typical tail-like structure. In some "centrifuged eggs" of the salamander, *Ambystoma*, the front end of the head, sometimes back as far as the gills, failed to develop. The interest of this observation lies in the demonstration that the hereditary determiners for development work out their destined end only when maintained in certain proper spatial relations. When displaced by the centrifugal machine they influence the production of their appropriate organs in abnormal positions. By reducing the abnormal pressure a point is reached where the determiners are not displaced and, hence, no abnormal development occurs. The limit serves, in a way, to measure the relative strength of hereditary and environmental forces in the given case of development.

BIOCHEMICAL PROCESSES IN HEREDITY.

Chemistry of Ontogeny, R. A. Gortner.

Development is a series of chemical processes which is directed by the presence of certain determiners that afford the hereditary control. A beginning has hardly been made upon the study of the chemical changes that accompany the morphological changes of ontogeny, yet this problem is of the greatest importance for evolution. For, just as the changes in form exhibited by an organism during ontogeny give some idea of the successive forms of the ancestors of the individual from the earliest to more recent times—and thus epitomizes the course of evolution of the species—so the chemical changes during ontogeny may well be considered to epitomize the evolution of the chemical characteristics of the species. And as there is much reason for thinking that the morphological changes have depended upon the chemical, it is obvious that the proposed study is of the greatest importance for evolution. The earlier experiments of Dr. Gortner on this subject were described in last year's report. Dr. Gortner continued this work by comparative analyses of the eggs and the newly hatched larvæ of the giant salamander, *Cryptobranchus alleganiensis*. The total dry weight diminishes by 1.6 per cent, due to loss of carbon dioxide and water, for the total nitrogen does not change. There is a gain of fats to the extent of 14

per cent over that in the egg. The greatest loss is from the protein fraction, some of which has gone into the fat. Dr. Gortner concludes:

"There is considerable evidence that the nitrogen ratios in the protein fraction are not fixed quantities, but that some amino acids are more necessary for the development of the embryo than are others, and as a result there is a continuous breaking down and recombining of the resulting radicals into new compounds. For example, the gain observed for arginine B, although small, is probably significant. It seems probable that there is, in the eggs of *Cryptobranchus*, a carbohydrate nucleus, either free (glycogen) or combined in the form of a glycoprotein, and that during the process of embryonic growth this carbohydrate is broken down to carbon dioxide and water, with a consequent liberation of energy for the 'Entwicklungsarbeit;' but the breaking down of the carbohydrate proceeds more rapidly than the needs of growth demand, with the result that the surplus energy is stored as fat."

Inhibition of Pigmentation, A. M. Banta.

In the last two reports attention has been called to our work in preventing the formation of black pigment in the little salamander, *Spelerpes*, by phenols. This year Dr. Banta used the same method with young larvæ of the giant salamander, *Cryptobranchus*, and got practically the same results. When small amounts of these inhibitors to the oxidation of tyrosin (a process which forms black pigment) are put into the tissues of the developing larvæ before pigmentation begins, the onset of pigmentation is markedly postponed and the pigment produced is much reduced in amount. Because of the toxicity of the inhibitors it is impossible to state how long these modifications would persist, for the larvæ, even though kept in the solutions for only 8 to 15 days, do not develop beyond the stage when the stored food in the egg is all utilized.

A Toxin of Bread Molds, R. A. Gortner and A. F. Blakeslee.

In last year's report the discovery (made in the course of studies on sex of molds) of a powerful toxic agent in the bread mold, *Rhizopus nigricans*, was alluded to. The full paper has now been published. The toxin has no effect when taken into the alimentary tract by a rabbit, whereas it is fatal to rabbits when injected intravenously in even so small an amount as 1 to 275,000 parts of body-weight, being one of the most poisonous organic substances known.

Modifying Effects of Cave Conditions, A. M. Banta.

The material in the cave and vivarium has been brought through with greater success than in any previous year. To the species previously maintained here have been added the blind cave-fish, *Amblyopsis spelæus*, and an additional species of salamander, *Ambystoma opacum*. During the present season large series of wood-frog tadpoles

were reared in the light and in the dark. Those developing in the vivarium were fairly black, as tadpoles of this species normally are, while those reared in the cave had very little pigment except in the eyes, and were so transparent that the heart and larger blood-vessels in the head and tail regions were visible externally. These larvæ and larvæ of the common spotted salamander, *Ambystoma punctatum*, when reared in the dark, have so little pigment that they resemble the cave-fish in the soft pinkish-white general body-color and in the reddish appearance of the heart region due to the large amount of blood showing through the transparent tissues. Again, this season many *Ambystoma punctatum* have been reared in the cave. One is struck by the relative lack of pigment in most individuals of this species developing in darkness. It requires close scrutiny to detect any pigment whatever, except in the eye. In every case, however, as the period of transformation approaches, the light individuals begin to develop pigment and by the time transformation is completed even the lightest individuals, though kept in the dark all the time, have developed a normal pigment complement. The *Ambystoma opacum* larvæ reared in darkness developed a reduced amount of pigment as compared with those reared in daylight, but the reduction is not nearly so large as with *A. punctatum*. *Spelerpes bilineatus* larvæ reared in darkness show only a comparatively slight reduction in pigment development. Species and, to some extent, individuals, show a marked difference in the amount of pigment reduction produced by developing in darkness. *Ambystoma punctatum* is very susceptible to the effect of darkness and develops very little pigment. *Ambystoma opacum* is much less influenced by the lack of light, and *Spelerpes bilineatus* is only slightly influenced.

Considerable numbers, both of the cave form and of the outside form, of the amphipod *Eucrangonyx gracilis* have been kept in the cave and in the vivarium. The cave form has no pigment except in the eyes, while the outside form has the normal amount of pigment for a crustacean. Young of the outside form, made to develop in the cave and consequently never exposed to daylight, have nevertheless formed body pigment in some cases and in others have no pigment except in the eyes. The young are only two-fifths grown and all may yet develop pigment. None of the series kept in the cave and derived from ancestors living outside caves has developed even approximately as much pigment as individuals of like size kept in daylight.

The work upon a comparison of the light and tactile reactions of the cave form and the above-ground form of this amphipod was completed while in Indiana in February. The results show conclusively that the cave form is considerably more reactive to tactile stimulation than the outside form. A definite measure for this difference in reactiveness was used and the results were obtained in precise terms. On the other hand, the cave form is somewhat less reactive to photic stimulation

than the form not living in caves. This difference is small but fairly constant. In general, so far as the evidence has been obtained, cave animals are *less* reactive to photic stimulation and *more* reactive to tactile stimulation than their near relatives living in other situations. This was notably true of the common *Asellus* and its eyeless and pigmentless cave relative, *Cæcidotea*, with which Dr. Banta experimented several years ago. The slightly modified cave form and the outside form of *Eucrangonyx gracilis* showed the same differences, but in a much smaller degree.

As a by-product of these studies a paper has been prepared by Dr. Banta and Dr. Gortner on an albino *Spelerpes* which was found while collecting and saved for purposes of breeding, but which died before reaching sexual maturity. It was an orange-yellow colored individual possessing the normal amount of yellow pigment, but without any black pigment in skin, eyes, or connective tissue. Aside from the albinic axolotl, it is believed to be the only recorded case of an albino urolele living in the open. Numerous albinic subterranean uroleles are, however, known.

HEREDITY.

Heredity of Some Emotional Traits, C. B. Davenport.

A large amount of time during the past two years has been spent in an analysis of family histories obtained by trained investigators. These histories comprised families with some greater or less criminalistic tendencies. As stated in my last report, the traits of more or less periodic outbursts of hysterical temper and uncontrollable eroticism are inherited as positive or dominant traits. Also, it now appears that a family tendency to periodic depression accompanied by a suicidal tendency is inherited as a negative or recessive character. Especially striking has been the result of study of cases of dipsomania and allied forms of alcoholism on the one hand and of nomadism or wanderlust on the other, which quite certainly prove an hereditary factor which is inherited as a sex-linked one. Data are also presented demonstrating the inheritable basis of inhibition or "moral control." The whole work, which is now ready for the press, is entitled "The Feebly Inhibited," and gives a first clear insight into the hereditary basis of conduct.

Heredity of Certain Mutations, C. B. Davenport.

Further study of the "bare-neck" poultry supports the view, expressed in my last report, of the dominant nature of the factor that prevents feathers from growing on the neck of these fowl. A brief note on this subject, with photograph, appeared in the Journal of Heredity for August. The case is important, since it is another clear example of a morphological defect that is inherited as a dominant.

Duplicate and Plural Determiners, G. H. Shull.

Dr. Shull's discovery of a clear case of duplicate determiners in the triangular capsules of *Bursa* has led him to consider generally the whole matter of aberrant heredity of this type. He distinguishes as "duplicate" determiners those which, when separated from each other, produce characters so like that they can not be distinguished from one another, while the term "plural" determiners (the more inclusive term) comprises two or more genes which independently produce a character or modify it in any way whatever which does not destroy its identity. A useful attempt at an explanation of the origin of duplicate determiners is then offered, according to which one of a homologous pair of chromosomes containing a determiner (D) becomes displaced in its synapsis, uniting with a chromosome that lacks D. Thus *two* synaptic pairs come to possess the determiner D, though in a simplex condition; and consequently the determiner, henceforth, behaves as duplicate. A similar result would follow if a determiner alone crossed from one synaptic pair to another. The consequences of the hypothesis are followed out in an important paper.

Cytological Studies on Heredity, C. W. Metz.

At this Station, from its inception, we have appreciated the importance of the study of chromosomes as "bearers" of heredity, and we originally had a laboratory of cytology. A vacancy having arisen (through the resignation of Dr. Gortner) we have secured the assistance of Mr. Charles W. Metz, who began work in June and who reports as follows:

"Prior to coming here in June I was engaged in a comparative study of the chromosomes in the Diptera, with especial emphasis on the genus *Drosophila*. This study brought to light a remarkable series of chromosome groups in the Drosophilas, which series was not only very interesting in itself, but showed that the material was exceptionally favorable for study through hybridizing, and through genetic work on individual species. For the latter reason, several species were bred extensively and attempts were made at crossing. The cytological results of these studies were published as 'Chromosome Studies in the Diptera: I. A preliminary survey of five different types of chromosome groups in the genus *Drosophila*' (Journal of Experimental Zoology, July 1914). Further breeding work was carried on with *Drosophila ampelophila*, in studying the inheritance of the 'apterous character.' The results of this study are in press in the American Naturalist.

"Since coming here in June I have been carrying on the cytological and genetic work which I already had under way, but on a much larger scale, and in addition I have been breeding the beetle *Bruchus quadrimaculatus* extensively. Of course much of my time has been occupied with securing equipment, getting the laboratory into good working condition, and organizing the investigations. No attempt has been made to complete any investigations, owing to the shortness of the time and to the fact that a good deal of the equipment has only recently arrived. The organization of the Laboratory is now almost complete and several lines of study have been considerably advanced, some of which are

nearing completion. Much time has been devoted to securing and preparing material for study during the winter. This has involved the dissection and cytological preparation of hundreds of specimens. Many preparations have been completed and studied, with numerous interesting results. In addition many thousands of flies have been bred and studied for genetic purposes. A more detailed account of these studies follows.

"Most of the cytological as well as the breeding work has centered in the genus *Drosophila,* because it offers an unusual combination of favorable characteristics, most of the species being comparatively easy to breed and exhibiting striking specific differences in their chromosomes. In addition to the 12 species reported in the above-mentioned paper, several others have recently been studied. All but one of these fall into the general scheme proposed for the others. One species, however, is remarkably unlike the rest cytologically, and is of exceptional interest because it is favorable for a study of the maturation and prematuration stages in the *male,* a condition greatly desired because of its bearing on previous breeding experiments in *Drosophila.*

"The cytological work on *Drosophila* falls into three divisions: One is concerned chiefly with the relation between the chromosome groups of different species. Thus far about 18 species have been studied with the following results: Each species has been found to possess a characteristic group of chromosomes. These chromosomes are arranged in pairs, which differ from one another in size, form, and behavior in such a way that they may be readily distinguished. Thus the individual chromosome pairs in any species may be separately identified and followed. This fact has made it possible to compare the different specific chromosome groups with one another, chromosome by chromosome, with the result that individual chromosome pairs have been homologized throughout the series, and that the different groups have been found to make up what appears to be a definite evolutionary series, in which the various steps can be clearly followed. The results demonstrate beyond any doubt the real existence of the phenomenon of chromosome pairing, an association of homologous maternal and paternal chromosomes; and they add very substantially to the accumulating evidence of the individuality and continuity of the chromosomes—all of which facts have a very direct bearing on the relation between chromosomes and heredity.

"The second phase of the cytological work depends entirely on the breeding results—*i. e.,* whether or not species-hybrids are secured. Since the crosses have not yet been obtained, no advance has been made here. This is the most important aim of my *Drosophila* work, and although only negative results have been given thus far, I am very hopeful of ultimate success, even though considerable time and effort may be required. The result depends largely upon how many species can be secured, especially species from distant localities. The opportunities are unique, without a parallel in plants or animals, and every effort will be made to secure the results.

"A third line of cytological work on *Drosophila* centers around a study of the maturation processes, especially in the males. Breeding experiments by Morgan, *et al.,* have indicated that (in one species at least) the relation of the chromosomes during synapsis is different in the two sexes—*i. e.,* homologous chromosomes have no effect on one another in the male, while in the female they have an effect, as shown by the phenomena of "crossing over," etc. I propose to determine, if possible, whether this is attributable to an evident difference in the maturation processes of the two sexes. The work has progressed far enough to show that there are most decided cytological differences, but not far enough to single out a particular one as responsible for the genetic differences.

"In addition to cytological work on the genus *Drosophila*, the chromosomes of about 20 species, representing various families of the Diptera, have been studied, with a view to learning more of the characteristics of the order as a whole. When the preparations made during the summer are studied, many more species will be added to the above and extensive material will be available for a comparative study of several families. Some features already appear to be clear. First, the paired association of chromosomes is characteristic of the Diptera as a whole. If any species lack it they are the exceptions. None such has yet been found. Second, several families of flies (Muscidæ, Sarcophagidæ, Syrphidæ, Anthomyidæ, Scatophagidæ, etc.) all appear to have the same number of chromosomes (12) and appear to be fairly uniform in their maturation phenomena. Perhaps it may be said that they have reached a state of equilibrium in these regards. The Drosophilas and their close relatives, on the other hand, exhibit great specific differences, both in chromosome numbers and in maturation processes. As a group they do not seem to have become stable.

"Since the phenomenon of chromosome pairing is so characteristic of the flies, and found nowhere else in anything like such a definite form, I have made a detailed study of it. This study is nearly completed and will appear as No. II in my 'Chromosome Studies in the Diptera.' In this investigation I have studied various species from a number of families, and have found the behavior of the chromosomes, as regards pairing, to be essentially the same in all. I have shown that pairing exists throughout the whole life of the insect, from the embryo to the adult, and in the germ-cells previous to the maturation stages. During each cell generation, somatic or germinal, the two chromosomes constituting a pair become closely associated, in fact almost fused, soon after cell division; then later they separate somewhat and lie side by side until the next cell division. In other words, the maternal and paternal chromosomes of a pair are associated with one another throughout the entire life of the animal, and once during each cell generation they become very closely united. These facts, of course, strongly suggest that the two members of a pair are qualitatively alike and that the members of different pairs are qualitatively unlike.

"The breeding work in which I have been engaged is of several different sorts. Primarily it has centered around the endeavor to cross different species of *Drosophila*, which I have demonstrated to possess different chromosome groups. In preparation for this work it has been necessary, first of all, to perfect methods for rearing the various species, which in itself has taken much time, because the food habits of some are very different from those of others. Nevertheless over 15 species have been bred successfully, and methods have been secured which will probably suffice for almost any species subsequently obtained. With cultural methods perfected another attempt is now being made to secure species hybrids.

"In addition to keeping up stock for hybridization work, four species are being extensively bred for genetic work purely within species. Four species have been selected, each representing a different type of chromosome group, and it is hoped that mutants will be secured, making it possible to test the chromosome hypothesis by breeding from them. If good series of mutations are secured in these 4 species, or in 2 or 3 of them, I will have a crucial test of the chromosome theory from the genetic side, for each species should give a definite result, characteristically different from the others. The work on *D. ampelophila* has shown the presence in that species of 4 groups of linked characters, corresponding to the 4 pairs of chromosomes. I have selected one species having this same group of chromosomes. From it I should get results like

those given by *D. ampelophila*. A second species being bred has four pairs of chromosomes also, but of a different sort (No. 2). In this the minute pair is lacking, and there are two small pairs in place of one large pair of the previous group. The linkage phenomena should be quite different here. A third species resembles the last, but has the minute pair present (No. 3). This is the species which is especially favorable for cytological study in the male, and I am laying particular emphasis on it. Already one character has appeared which seems to be a mutation, although further breeding is necessary to make it certain. The fourth species has 6 pairs of chromosomes (No. 4), all of which are relatively short. This species should give six groups of linked characters as contrasted with 4 or 5 in the others, and the linkage should be very 'close,' since the chromosomes are short. In this species a definite mutation has just arisen, out of many thousand flies examined. Only the F_1 has been secured, but the character appears in this, leaving no doubt about the reality of the 'mutation.' The 4 chromosome groups are shown diagrammatically in figure 6.

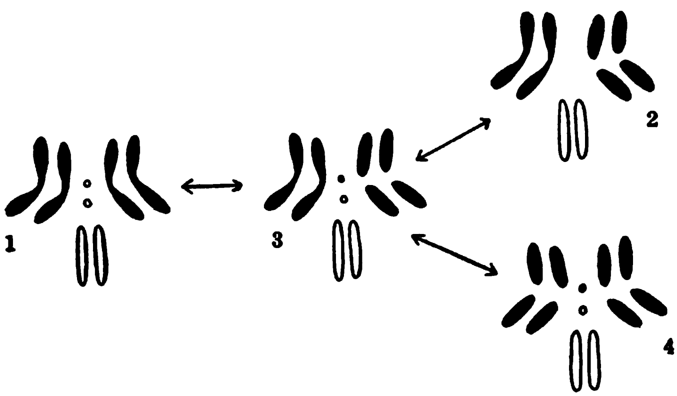


FIG. 6.

"If mutations of similar sorts appear in the different species, as I am confident will be the case, a further and much more detailed analysis can be made, and the relation between homologous chromosomes in different species can be shown.

"While engaged in working out methods for handling Drosophilas I have also experimented with methods for breeding larger flies of various species. This work has resulted in satisfactory methods for rearing 6 or 8 species of the so-called 'higher flies,' and has furnished large amounts of cytological material. It has not seemed advisable to carry these cultures further this year, except for the provision of cytological material.

"As an auxiliary investigation, quite aside from the Diptera work, I am breeding beetles of the genus *Bruchus* (*B. quadrimaculatus*, the cow-pea beetle). The material shows a great range of color patterns and offers excellent opportunity for some phases of breeding. Two generations have been secured thus far (3 months) from an originally mixed stock, and different lines are becoming purified. When this process of selection is completed, the inheritance of the characters will be tested by crossing. Nothing very definite can be said about the results as yet, except that either a large number of factors is involved, or else some very changeable factors are operating. Cytologically the species is good for study, but the number of chromosomes is far too great to allow of such work as is being done with the Drosophilas."

SELECTION AND PURE-LINE WORK.

This field of study deals with problems of the greatest present-day interest. Doctors Harris, Banta, and MacDowell are carrying on this work.

Studies on Selective Mortality, J. A. Harris.

For several years the problem has been investigated whether in a lot of planted seeds of one species there is a selective elimination of any type or whether each occurs strictly at haphazard. Recently Dr. Harris has planted about 46,000 individually weighed seeds of the bean (*Phaseolus vulgaris*), treated them alike, and classified their subsequent history into three groups: (1) seeds that germinated normally; (2) seeds that germinated by producing more or less abnormal seedlings; (3) seeds that failed to germinate. Comparing the weights of the planted beans that had respectively these three fates, it is found that the average weight of all the varieties of beans that germinated normally and of those that failed to germinate was nearly the same, although in two varieties of bean there is a distinct superiority in the mean weight of the survivors, while in one other variety there is a pronounced inferiority in the mean weight of the survivors as compared with those that failed. But, on the other hand, when absolute variabilities of the three sets of progeny are compared, it appears at once that *seeds that germinate vary less around the mean than those that fail to germinate.* When variability is expressed in units of the mean weight it appears still more clearly that the seeds that germinate are a selected lot—selected for their closeness to the mean weight of all the bean seeds of their variety; the seeds of aberrant weight are less apt to germinate. In so far as the weight-aberrancy is an inheritable trait, it is easy to see that the greater mortality among the aberrant seeds will tend to hold the race to the mean or "typical" seed weight. In general, selective mortality operates conservatively, tending to preserve pure the specific characters. These studies have been extended to peas, and in these, also, the seeds that germinate are on the whole less variable than those that fail to germinate. In comparing the weight of the seeds that germinated promptly with those that developed slowly, it became necessary to get the exact time of germination of these 46,000 seeds; and that involved observing at night as well as in the day. As a by-product, the law was established that, in beans, the heavier the seed the more slowly it germinates.

Relationship between the Weight of the Seed Planted and the Characteristics of the Plant Produced, J. A. Harris.

The fact that a certain quality (such as aberrancy of seed weight) is associated with exceptionally great mortality is no evidence that the first quality is the cause of the second. It may be that the first cause

induces a third or a chain of events which are the true causes of the high mortality. Consequently it becomes of importance to know what other characters are correlated with weight of the seed that has been planted. Dr. Harris has shown that in beans there is a sensible relationship between the weight of seed planted and (1) the number of pods on the plant that develops out of that seed; also (2) the number of ovules and the number of seeds in the pod produced by the plant developing from it.

Factors Influencing the Weight of Seeds and their Number in a Pod, J. A. Harris.

In beans, the weight of seeds decreases as the number of seeds per pod increases; also, the seeds are the heavier the farther they are from the attached end of the pod. In fact, the free end of the pod seems more favorable for the fertilization and development of the ovules in the pod. But, remarkably enough, the number of ovules per pod seems not to influence the weight of the seeds eventually developing in the pod in beans. In another legume, *Cercis canadensis*, there is a marked positive correlation between the number of ovules and of ripe seeds in a pod. As a corollary about the same proportion of the ovules are fertilized and develop, whether the number of ovules be small or great; if anything, the pods with the larger number of ovules produce relatively fewer seeds. Dr. Harris has summed up results of his recent work on selection in a paper, "Current Progress in the Study of Natural Selection," published in the Popular Science Monthly.

Selection of Strains of Daphnia with reference to Reaction to Light, A. M. Banta.

The selection in a parthenogenetic species for greatest and least sensitiveness to light has been continued now for 110 generations in some cases and the number of individuals measured approaches 20,000. The results continue to show an effect of selection in some lines, but not in all, and the differences are in most cases statistically significant. The differences produced by selection have become largest in lines of the species (*Simocephalus*) which for a long time seemed the least responsive to selection.

Incidentally to the foregoing investigation, the result has been gained that 100 generations of *Daphnia pulex* have been reared parthenogenetically without sexual forms appearing at any time. There is no evidence of decreased vigor or loss of vitality in the lines. Hence, it appears that there is not a necessary sexual cycle in the reproduction of this daphnid. These observations lend additional evidence to the conclusion that the sexual cycle in *Daphnia* is not an inherent, necessary thing, but that it is determined by external conditions.

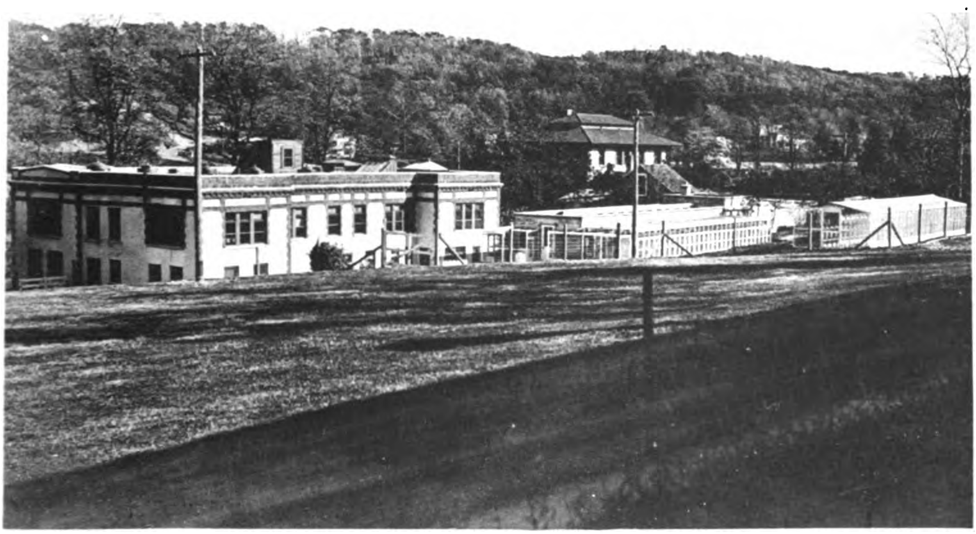
Selection of Unstable Determiners vs. Plural Determiners,
E. C. MacDowell.

Dr. MacDowell is studying the question of the stability of Mendelian genes or determiners which is a central topic for many investigations, chiefly because of the extensive work of Dr. W. E. Castle. He reports as follows:

"If genes are stable and are passed from generation to generation unmodified by their associations with other genes, the work of selection consists merely of sorting out certain combinations of homozygous factors. After this is done, selection can produce no further changes. If genes are modified by the other genes in contact with which they come, new genes as well as new somatic appearances can be produced by selection. The work of Professor W. E. Castle and Dr. J. C. Phillips on modifying the color patterns of rats by selection, reported in the Year Book for 1913, has been interpreted by these investigators as showing that selection is effective in modifying Mendelian genes and so in producing new kinds of genes. Their interpretation is not the only one applicable. It is possible to suppose that the apparent success of selection was due to the sorting out of multiple genes, which have been assumed by the authors to explain certain phenomena of crossing. Work bearing closely on this subject has been undertaken on the banana fly (*Drosophila ampelophila*). A race of flies has been produced lacking a restrictive gene that limits the number of bristles on the back of the thorax in the normal flies to four. In the absence of this gene the number of bristles is variable, but greater than four. By the closest inbreeding and selection the number of extra bristles was steadily increased for six generations; after this no further increase has been detected. At present the race is in the twenty-first generation. This result, supported by certain other very definite phenomena, has led to the tentative adoption of the hypothesis that there are accessory genes which, in the absence of the main restricting gene, hold down the numbers of extra bristles, and that the success of selection at first is to be accounted for by the dropping out of these accessory genes by using parents with high bristle numbers, which in successive generations lacked more and more of these accessory genes. After the sixth generation a state of equilibrium was produced in which these genes either were all removed or homozygous. This interpretation, involving more than one determiner for a single somatic character, is much like that reported by Shull in the Year Book for 1913, for his work on shepherd's purse. The attempt is being made to test this hypothesis by isolating lines of extra-bristled flies that show constant differences in bristle number, and by crosses between these lines to determine whether or not the differences between the lines are due to accessory restrictors. Before this can be satisfactorily attempted, special studies on the causes of the fluctuations in the bristle-numbers must be undertaken in order to reduce these non-genetic variations. It has already been found that the size of the fly, which varies with the *amount* of food eaten in the larval state, influences strongly the number of extra bristles, as a small fly is apt to have very few extra bristles (1 or 2) and a large fly many (5 to 8). This is a good example of the influence of environment on the development of a Mendelian character, and emphasizes the necessity of careful investigation of the role of environment in all genetic work.

"Besides the plan outlined above, future work will include (1) further selection for increase in the bristle numbers, so that the failure of selection can be absolutely unquestioned, and (2) return selections, *i. e.*, starting with the inbred and selected race, low-grade parents will be selected instead of high-grade. If factors or genes may be modified, a complete return selection should be possible. If the first success of selection was due to the dropping out of ac-

1. Front of New Animal House.



2. Buildings at Station for Experimental Evolution: from left to right, Animal House, Pigeon Houses, Greenhouses and Laboratory in the background. View looking southeast.

cessory restricting genes, this return selection should not accomplish any genotypic change. Up to date these investigations include over 670 pedigreed families and bristle-counts from considerably over 71,000 flies."

METHODS.

As heretofore, considerable attention has been given to the development of statistical methods suitable for dealing with problems in hand and to calculating tables to facilitate computations. A memoir has been issued, by Dr. Harris, on the calculation of intra-class and inter-class coefficients of correlation from class moments when the number of combinations is large. Tables to facilitate the calculation of osmotic pressure and the mean molecular weight of solutions have been prepared by Drs. Gortner and Harris.

A note has been published in "Science" on a new collecting pipette which some of the supply firms have already expressed an intention of figuring and listing in their catalogs. The pipette is useful in collecting small objects in difficult places and especially in handling delicate specimens. It was devised by Dr. Banta.

Dr. R. A. Gortner has published a device for freeing a precipitate from mother liquor when filtering by suction.

CONSTRUCTION AND EQUIPMENT.

MAIN BUILDINGS.

During the year under review the buildings started in 1913 and described in the last Year Book were completed as far as at present contemplated. The power-house has been in satisfactory use since December 1 and has demonstrated that it can heat the plant with economy and efficiency. During the summer the steam pipes were extended by our own workmen to the greenhouses and to the old laboratory. The hot-water system of the greenhouse is now heated by steam by means of a Griscom-Russell heater. The radiators of the old laboratory have been united with the vacuum system. Since it seemed probable that we should not at present use enough electric power to warrant installing a generator, our plant has been connected up with the street main, and lights put in the greenhouses and three ground lights at points where they will be most useful on dark nights. The air-conditioning apparatus, providing for control of temperature and moisture, is about to be installed.

MISCELLANEOUS.

Six new concrete cold frames were installed, and steam-heating pipes were placed in the concrete pigeon-house and connected with the animal house. New concrete coal-bunkers were built into the hillside, and a concrete retaining wall built back of the animal house. A second concrete bridge was built over the ravine, a garage provided, a gasoline storage-tank installed, chemical laboratory furniture made, and the library room enlarged. New out-door pigeon flies were erected and numerous bits of fencing and cabinet work done. An electric fire-pump was installed in the power-house and connected with the reservoir of the artesian well. The drive to the laboratories was surfaced with stone.

GEOPHYSICAL LABORATORY.*

ARTHUR L. DAY, DIRECTOR.

In studying the minerals which participate in rock formation, we should bear in mind always that the main purpose of such studies is not merely to add to the list of known compounds whose elementary properties have been measured, but rather to learn the important characteristics of the component members of a great number of systems of mineral mixtures which we call the natural rocks. A knowledge of the characteristics and relations of these component minerals provides the only possible approach to a competent knowledge of the manner of formation of the earth. We are not able as yet to follow Nature in her full complexity; in fact, we know at the moment very little of the conditions of formation or of the relations of the minerals in the more common igneous rocks. Recognizing this fact, we turn from the complex rocks to the simpler component minerals, and finding these in turn complicated by the admixture of other minerals and of volatile matter, the relations of which we can not for the moment solve, we turn finally to chemically pure minerals, prepared and crystallized in the laboratory, upon which we seek to establish the foundations of the system of knowledge which will one day result from such studies.

Pursuing this plan, the first task to which a laboratory dedicated to the study of this problem must address itself is the preparation of mineral types representing the individual components from which rocks are made. It is necessary to make these in the laboratory, because they are almost never found in nature entirely free from admixtures of small quantities of other minerals which behave like impurities and serve to veil the characteristic properties of these primary ingredients. When it was found practicable to prepare these mineral types in a state of high chemical purity, the first step in an exact science of the mineral relations was taken. The thermal and optical properties of these primary components could then be studied at leisure; the conditions for their absolute identification could be established; their individual stability in the various conditions of rock formation fixed, and the characteristic properties which they exhibit in their relations with other minerals determined.

Following upon this segregation of the primary components in rock formation, and the determination of their characteristic properties, both physical and chemical, the investigation proceeds with constructive sequence to discover the relations between two such components when mixed together in all proportions and under measured conditions (temperature, pressure, surrounding atmosphere, etc.) corresponding

*Situated in Washington, D. C. (For previous reports see Year Books Nos. 3–12.)

as nearly as may be with what we may imagine the conditions of natural rock formation to have been. The character of the product will often determine whether the conditions were really those of nature or not, and thus we obtain our first direct clue to the conditions which governed the formation of natural igneous rocks. These simple problems of two minerals in different relations have been found to admit of reasonably complete solutions in a great variety of cases which have been reviewed from time to time in these annual reports and have been published in full detail in appropriate scientific journals.

Pursuing the same reasoning, the next step of importance was to bring together three of these primary components in all the combinations which could reasonably be expected to have significance in rock formation, and to study these under the same variety of (measured) conditions to which the binary mixtures have been subjected. Obviously, this was to be a task of enormously greater magnitude than those which had preceded it, and so indeed it has proved, but it has now been successfully accomplished—the first strictly quantitative study of its kind, so far as we are aware.

THE MINERAL SYSTEM LIME-ALUMINA-SILICA.

Speaking technically, this problem is the determination of the temperature-concentration equilibria in the three-component system, lime, alumina, silica. It is important from the purely scientific standpoint as a study of the physico-chemical behavior of a complex silicate system at high temperatures in which the results obtained find direct and fundamental application in the investigation of rock magmas and lavas; it is important for the technical world because of its bearing on the constitution of portland-cement clinker. Commercial portland cement is simply this clinker finely ground and moistened with water, after which it sets and hardens in a short time to a rock-like mass. Experience has shown that the qualities of portland cement are directly dependent on the mineral composition and the physical properties of this original clinker. Chemists have determined the variations permissible in the *chemical* composition of the clinker, and cement experts have devised suitable methods of preparing the clinker to obtain a sound commercial cement. Much has also been written on its probable mineral composition and on the processes involved in the setting of cement, but the present investigation fixes the *mineral composition* of the clinker for the first time, and thus furnishes a definite basis for the definition of the factors involved in the more strictly commercial aspects of the problem.

The present investigation has extended over a period of nearly eight years. When it was started, the possibility of resolving such a complex silicate system was uncertain because suitable methods of attack were not available for the purpose. The study was therefore begun with

the simplest parts of the system and the different thermal and optical methods essential for such work were devised, tested, and improved as the work progressed. As a result, a large part of the time expended has been required for the development of methods which are now perfected and have been found satisfactory and easy of general application.

In the study of the lime-alumina-silica system, fully 1,000 different mineral preparations have been made up and over 7,000 heat treatments and microscopical examinations undertaken upon them. These preparations and the results obtained with them are filed and are available for future reference. A brief statement of the data obtained and also of the physico-chemical interpretation of these data is given in the paper by Rankin and Wright, of which a brief review will be found on page 155. The problem will be treated in greater detail and the methods which are of general interest and importance will be described in a later monograph.

Incidentally, it is interesting to note that in the ceramic, glass-making, and allied industries these methods of combined physico-chemical and microscopical research are attracting inquiry and are being gradually adopted. In particular, the petrographic microscope has proved to be a most efficient and simple tool in the service of such industrial research and its use is certain to become increasingly important as this fact is realized by the technical world.

In the annual report for 1912 (Year Book No. 11, page 98) the purpose of these studies of lime, alumina, and silica was stated to be to ascertain:

(1) All the compounds of these three ingredients which are possible.
(2) The temperatures within which each of these compounds is stable and therefore capable of independent existence.
(3) The relation between each compound and any or all of the others at whatever temperature.
(4) The behavior of these individual compounds or groups of them in the presence of water at various temperatures.
(5) The application of this information to the study of natural rocks or to the making of artificial rocks (cements).

Of these studies the first three, which bear directly upon our problem of rock formation, are completed and in press. The fourth applies more specifically to hydraulic cements and hardly enters into the problem of igneous-rock formation. Accordingly, although we had already done some work upon this phase of the investigation also, it was practically discontinued as soon as we learned that a much more appropriate institution, the Bureau of Standards, had made provision for extensive studies in the same field. There appeared to be no reason for a duplication of activities which were leading in a direction somewhat apart from our primary purpose.

The applications (paragraph 5) of the methods and data which have been gathered in these studies have proved to be manifold and

extensive, as was to be expected. In fact, through the experience gained in this work it proved practicable to carry out a second three-mineral system (lime, alumina, magnesia) similar to the first within a period of a few months.

THE SECONDARY SULPHIDE ENRICHMENT OF COPPER ORES.

Since about the year 1900 the problem of the secondary enrichment of ores has been growing in interest, and certain phases of it have been studied as opportunity offered, both in the laboratory and in the field. In 1911, Professor L. C. Graton, of Harvard University, planned a much more comprehensive study than has been undertaken hitherto, of one particular phase of this problem, namely, the secondary sulphide enrichment of copper ores. He was fortunately able to enlist the interest and the cooperation of the copper-mining industries, which secured for him special privileges to examine all the principal copper-sulphide mining districts of North America.

This fact of itself is of more than passing interest, for although cooperation between science and industry has been much cultivated in other countries, notably in Germany, and without recorded exception has resulted in great advantages to both participants, but little open cooperation of this character has been attempted in the United States. There would seem to be no reason why American science and industry might not enjoy similar benefits where their common interests are involved.

Recognizing the necessity for laboratory studies on the conditions of formation of the copper-sulphide minerals, the means for identifying them, and the alterations to which they are subject, Professor Graton proposed to this laboratory that such investigations be undertaken here in direct collaboration with those who might be chosen to undertake the systematic field investigation which he proposed to inaugurate. After some consideration of the scope of the plan proposed, which was rather too large for the resources at our disposal for such a purpose, but in full appreciation of the advantages which such cooperation might offer, the invitation was accepted. In fact, at the moment when the invitation was received, laboratory work on the stability of the sulphides of copper and the relations between them was already in progress, following upon similar work upon the sulphides of iron, of cadmium, and of mercury, the successful results of which enabled us to proceed with full confidence in the outcome of the larger plan now proposed.

The difficulty in the matter of resources was happily removed by an allotment from the funds at the disposal of Professor Graton.

Thus the systematic study of one of the larger problems of geology, a problem of interest equally from the scientific and the economic viewpoints, was inaugurated early in 1912 under the most favorable conditions and has been prosecuted with vigor and success since that time.

Some details of the plan as at first proposed were contained in the annual report of this laboratory for 1913 (Year Book No. 12, p. 129). The present status of the investigation, or rather of the laboratory portion of it, follows.

What is secondary enrichment? It is now generally conceded that when the sulphides of an ore body oxidize at the surface of the ground and pass into the soluble form, they are carried down by percolating waters and reprecipitated on the surface of the still unoxidized sulphides below. The chemical reactions involved in this process and the physical conditions which favor them have been heretofore only matters of conjecture. The laboratory problem involves the elucidation of these processes, as well as the somewhat broader problem of the stability relations between copper and the copper and iron sulphides: chalcocite Cu_2S, covellite CuS, chalcopyrite $CuFeS_2$, and bornite Cu_5FeS_4; it involves the synthesis of these sulphides under known conditions, including, of course, the conditions of natural formation where known and the most important alterations which are found to occur.

The most obvious manner of attack is to start from the pure chemical elements copper and sulphur, and from these to endeavor to make, in the laboratory and under measured conditions, the compounds of these, or, in a word, to study the relations between pure copper and pure sulphur over a sufficient temperature range to include all the natural combinations of these two substances which are known. Heating these two elements together results first of all in the formation of the simple 1:1 compound CuS, corresponding to the mineral covellite, which then appears stable up to about 360° C. Beyond this temperature (in H_2S at atmospheric pressure) it begins to lose S, but microscopic examination shows that the mass remains homogeneous, which may be interpreted to mean that the covellite has lost its stability and yielded place to a lower sulphide of copper carrying sulphur in solution. Continued heating drives out this dissolved sulphur gradually, until in vacuo at 1127° C. the charge melts as Cu_2S, corresponding to the natural mineral chalcocite. The progress of this reaction has been checked by observation at several intermediate temperatures, at each of which the charge is exposed until no further change occurs there, after which the product is examined. The results are tabulated below:

Temperature.	Dissolved sulphur.	Specific gravity (25°).	Color.	Product.
° C.	*p. ct.*			
410	2.89	5.562	Light	$Cu_2S(S)_x$
485	2.32	5.638	Darker	$Cu_2S(S)_x$
700	1.75	5.666	Still darker	$Cu_2S(S)_x$
1050	1.66	5.675	Do	$Cu_2S(S)_x$
1060	1.66	Melting temperature in H_2S (1 atm.)		$Cu_2S(S)_x$
1127	0	Melting temperature in vacuo		Cu_2S

The change in the measured properties is thus shown to be a continuous one, and the sulphur in solution is found to lower the melting temperature of chalcocite, as might be expected.

The relation of these intermediate solutions to chalcocite and covellite is in every way analogous to the relations of the various pyrrhotites, $FeS(S)_x$, to ferrous sulphide and pyrite, and since the pyrrhotites are common in nature, chalcocite solutions might also be expected. Nevertheless, the field evidence shows that whereas the pyrrhotites are found more commonly in nature than ferrous sulphide, Cu_2S is certainly more common alone than with excess sulphur in solution.

Thus far, chalcocite alone has not been obtained in the wet way from cupric solutions, but mixtures of the covellite result. When covellite is heated with an excess of alkali sulphide, a part of it is changed into chalcocite with formation of polysulphide, while when polysulphide is heated with chalcocite, part of the latter becomes covellite. The reaction $Cu_2S + Na_2S_2 = 2\,CuS + Na_2S$ is therefore reversible.

At this point the investigation was interrupted until a method could be worked out for the determination of covellite and chalcocite, each in the presence of the other, and this has now been successfully accomplished. (Reviewed under (46) p. 156.)

Simultaneously with the above investigation of the relations between sulphur and copper, a similar study of the system copper, iron, and sulphur was undertaken, and, although more complicated than the first, is also well advanced. Chalcopyrite and bornite have both been successfully prepared in the laboratory and a method for their determination is available. Also the composition of pure bornite has been found not to be Cu_3FeS_3 as commonly stated in the books, but Cu_5FeS_4.

Conjointly with these experiments on the formation of the copper-sulphide minerals and their relations, direct experiments have been in progress for some time on the changes which actually take place during the processes of secondary sulphide enrichment.

In nature we find indications that the solutions from the oxidized sulphide zone have produced a series of changes in the sulphides beneath them, as follows:

Pyrite changes to chalcopyrite	$FeS_2 \longrightarrow CuFeS_2$
Chalcopyrite changes to bornite	$CuFeS_2 \longrightarrow Cu_5FeS_4$
Bornite changes to covellite	$Cu_5FeS_4 \longrightarrow CuS$
Covellite changes to chalcocite	$CuS \longrightarrow Cu_2S$
Chalcocite (rarely) changes to copper	$Cu_2S \longrightarrow Cu$

After more than a year of work, we now know that all these changes can also be effected in the laboratory by the action of copper-sulphate solutions on the sulphides, and will therefore be accessible to detailed study. Most of these changes are very slow at low temperatures and more rapid at higher ones. The laboratory work has therefore been done for the most part at 200° C., but the same reactions have been

found to occur at 100° C., and indications of the same reactions or some of them were also found at 30° C. The conditions of deposition in nature are therefore also accessible and the results comparable with those of the laboratory. Moreover, these reactions have been worked out in a quantitative way, *i. e.*, the quantities of all the products formed have been carefully determined. The ratios of the iron dissolved and of the sulphuric acid which is formed to the copper precipitated have been determined in all the cases. In some of the cases chemical separations of the products can also be made. Thus the following changes have been established:

Pyrite to chalcocite	$FeS_2 \longrightarrow Cu_2S$
Covellite to chalcocite	$CuS \longrightarrow Cu_2S$
Chalcopyrite to chalcocite	$CuFeS_2 \longrightarrow Cu_2S$
Pyrrhotite to chalcopyrite	$FeS(S)_x \longrightarrow CuFeS_2$
Bornite to chalcocite and covellite	$Cu_5FeS_4 \longrightarrow CuS+Cu_2S$

Color changes and incomplete chemical investigations indicate also:

Pyrite to chalcopyrite	$FeS_2 \longrightarrow CuFeS_2$
Pyrite to bornite	$FeS_2 \longrightarrow Cu_5FeS_4$

Again, the change at ordinary temperatures from bornite to covellite and chalcocite, $FeS_2 \longrightarrow Cu_2S$ and CuS, has been quantitatively worked out and at 300° C. we have found the change $Cu_2S \longrightarrow Cu$.

All these changes involve an increase of copper in the product, that is, an enrichment.

Thus far, the conditions which determine any particular one of these changes at 200° C. can only be stated in general terms; thus, for example, the higher the concentration of copper solutions and the longer the time and the greater the surface of sulphide exposed, the farther the change will go. A large surface of pyrite and a dilute copper solution gives at first considerable chalcopyrite, but eventually all becomes chalcocite. Certainly none of the intermediate copper sulphides between pyrite and native copper can be regarded as stable in the presence of copper-sulphate solutions. Since sulphuric acid is one of the products formed in the oxidation zone whenever pyrite, marcasite, or pyrrhotite is present, we have studied the effect of copper-sulphate solutions on the common sulphides in the presence of acid as well as in neutral solutions. In one instance (the change from pyrite to chalcocite), acid has been found to retard the precipitation of copper, *i. e.*, the enrichment process. Now, mine waters have been proved to be less acid the lower the level. The acid is neutralized by various minerals, like the carbonates, feldspars, and others, with which the solutions come in contact. Therefore we should expect that enrichment would go on more rapidly at some distance below the surface, the distance depending on local conditions.

In these various ways the problem is leading to a series of reactions bounded by definite conditions which admit of laboratory study and precise definition. This problem will be pursued actively during the coming year.

PUBLICATIONS.

Brief reviews of the papers published by members of the Laboratory staff during the current year follow.

(1) **The utilization of diffusion processes in the preparation of pure substances.** John Johnston. J. Am. Chem. Soc., 36, 16–19 (1914).

Many slightly soluble substances, when formed by precipitation in the ordinary way, are very fine-grained, and consequently contain occluded impurities which are not easy to get rid of; but by taking advantage of the slowness of diffusion in liquids, one can secure very slow precipitation, and in this way prepare such substances in relatively large crystals free from impurity. By this means, for instance, one can readily obtain crystals of calcium hydroxide ($Ca(OH)_2$) in the form of hexagonal prisms 3 mm. long with the base 1 mm. thick, or crystals of barium sulphate as much as 2 mm. long.

(2) **A method for determining magnesium in calcium salts.** J. C. Hostetter. Jour. Ind. Eng. Chem., 6, 392–396 (1914).

The usual methods for the determination of magnesium in the presence of calcium are not applicable when the latter element amounts to as much as 1,000 times that of the magnesium. The essential feature of the method here presented is the concentrating of the magnesium into a precipitate containing but a small amount of calcium. This concentrating is effected by precipitating $Mg(OH)_2$ with a slight excess of solid $Ca(OH)_2$. The magnesium in this precipitate is determined as pyrophosphate after removal of the calcium by two oxalate precipitations. Determinations in some 30 highest-grade calcium salts show, generally, far more magnesium than reported by the makers.

(3) **Calibration tables for copper-constantan and platinum-plantinrhodium thermo-elements.** L. H. Adams. J. Am. Chem. Soc., 36, 65–72 (1914).

Thermo-elements, if they are to yield accurate readings of temperature, must frequently be recalibrated by determination of their electromotive force at a series of fixed points and subsequent interpolation. The labor of interpolation is minimized by the aid of the tables presented in this paper, which give temperatures and temperature differences for each 100 microvolts up to the limit of usefulness of each thermo-element, and are used in combination with the appropriate derivation curve deduced for each element from the observations at the fixed points.

(4) **The occurrence of molybdenum in rocks, with special reference to those of Hawaii.** John B. Ferguson. Am. Jour. Sci. (4), 37, 399–402 (1914).

This article deals with the unexpected discovery of traces of molybdenum in two basaltic lavas from Hawaii and the question of the distribution of this element in igneous rocks. Its presence in the two basalts reopens the question of its occurrence, since it was thought to be confined entirely to the more siliceous rocks. Tests were accordingly made on a trachyte obsidian from Hawaii, on some sodic, and especially on some nephelite-bearing igneous rocks from other localities. From these it would appear that the presence of molybdenum is not correlated with high soda or potash content. Except for its well-known tendency to occur in the more siliceous rocks, it therefore seems to be influenced by regional rather than by general chemical characters.

(5) **The optical properties of azurite and alamosite.** H. E. Merwin. J. Wash. Acad. Sci., 4, 253–254 (1914).

For sodium light, the optical constants of the two minerals are as follows: Azurite, $\alpha=1.730$, $\beta=1.758$, $\gamma=1.838$, $2V=68°$; alamosite, $\alpha=1.947$, $\beta=1.961$, $\gamma=1.968$, $2V=65°$.

(6) **Das Studium der Mineralschmelzpunkte. Arthur L. Day. Fortschritte Min., 4, 115–160 (1914).**

A critical review of the work of recent years in the determination of the melting temperatures of the minerals, in which an effort has been made to clear up some of the confusion which now prevails in this field of research. Some attention has been given to the applicability of the laws of solutions to the change of state of minerals and to the criteria available for the definition and experimental measurement of those changes of state which can be competently studied with the methods and apparatus thus far developed. The effect of disturbing factors, such as viscosity and inertia, which frequently intervene to delay or prevent the establishment of equilibrium in the system, and so compel the use of methods of approximation, has also been considered, together with the effect of admixtures of minor mineral components in natural mineral types. A sharp distinction is drawn between the characteristic properties of single minerals and of groups of two or more in solid solution. The failure to recognize and properly to appraise this distinction appears to have been the cause of a considerable part of the confusion alluded to above.

Following these general considerations, several pages are devoted to the description of the apparatus now in use in the various laboratories for the determination of mineral melting-points, together with the limitations encountered in its application to such studies and to the interpretation of the results obtained with it. The effect of pressure upon the change of state in minerals is also considered.

The closing chapter contains a table of all the melting temperatures of record, in which appropriate attention has been given to the chemical purity of the specimen studied.

(7) **Einige neue Doppelkompensatoren. Walter P. White. Z. Instr., 34, 71–82; 107–113; 142–151 (1914).**

This paper deals with the construction of potentiometers possessing the high precision needed for accurate work with thermo-elements. Two general features of value are: (1) The use of the *partial deflection* method, where the quantity to be measured is largely compensated or balanced, and the outstanding small difference read directly by some deflection instrument. Such methods usually combine all the precision of null methods with almost the quickness of straight deflection methods. (2) The use of neutral ("anti-thermoelectric") contacts, especially in the switches. This renders it possible to dispense with the very low contact resistance required in many existing instruments, and also brings other advantages. Neutral contacts are easily secured by simply using thin leaves of metal, adding blocks of the same metal in dial switches.

Various electrical arrangements for high-precision potentiometers, suggested by Wolff, Waidner, Hausrath, Diesselhorst, Wenner, and the present writer, are examined in detail. The preference is given to a "split-circuit" potentiometer (embodying features due to Wenner and White) somewhat different from previous split-circuit designs, and to a new type, the "combination potentiometer" (features due to Hausrath, Diesselhorst, White), which requires two batteries, but is otherwise remarkably simple and free from sources of error.

One advantage of the potentiometer is the ease with which it can be adapted to almost simultaneous readings of different electrical quantities. A potentiometer with two sets of switches is especially effective in this respect, and practically does the work of two instruments. The two sets of dials are controlled either by a master switch or by sliding two sets of switch arms over a

single set of central blocks. This latter arrangement is easily secured in the "gridiron" potentiometer, by means of a new and simple type of switch construction.

Instruments now in use in this laboratory are described which illustrate the above types of design and construction.

(8) The binary system $MgO-SiO_2$. N. L. Bowen and Olaf Andersen. Am. Jour. Sci. (4), 37, 487–500 (1914.)

Equilibrium in the binary system $MgO-SiO_2$ was studied by applying the method of quenching.

There are two compounds, the orthosilicate Mg_2SiO_4 and the metasilicate $MgSiO_3$, capable of existing in contact with liquid in the binary system. The former crystallizes in a form corresponding with the mineral forsterite and the latter forms crystals similar to enstatite in most properties, but of monoclinic symmetry, clino-enstatite.

Clino-enstatite is the only stable form of $MgSiO_3$ encountered. It has no true melting-point, but breaks up at 1557° C. (formerly considered the melting-point) into forsterite and liquid, and the temperature must be raised to 1577° C. before complete solution of the forsterite takes place.

In an earlier publication from this Laboratory, crystals termed α-$MgSiO_3$ were described as a high-temperature form of magnesium metasilicate. They were considered to be the product of inversion of clino-enstatite (β-$MgSiO_3$), but the crystals described have now been proved to be a product of the dissociation at 1557° C. and to be the orthosilicate forsterite, not a form of the metasilicate.

On account of the break-up of clino-enstatite into forsterite and liquid there is no eutectic between the two compounds, and the liquids show, on cooling, the partial or complete ré-solution of forsterite at the reaction-point, 1557° C., the liquid reacting with the forsterite crystals to give clino-enstatite.

A discussion is given of the geological significance of this resorption of the olivine forsterite, by reaction with the liquid to give the pyroxene clino-enstatite.

Summary of invariant points.[1]

Solid phases.		Liquid phase.	Temperature.
Periclase	(MgO)	MgO 100%	2800° (Kanolt)
Periclase Forsterite	(MgO) (Mg_2SiO_4)	<14% MgO >86% Mg_2SiO_4	1850° ± 20°
Forsterite	(Mg_2SiO_4)	Mg_2SiO_4 100 %	1890° ± 20°
Forsterite Clino-enstatite	(Mg_2SiO_4) ($MgSiO_3$)	$MgSiO_3$ 97.5% SiO_2 2.5%	1557° ± 2°
Clino-enstatite Cristobalite	($MgSiO_3$) (SiO_2)	$MgSiO_3$ 87.5% SiO_2 12.5%	1543° ± 2°
Cristobalite	(SiO_2)	SiO_2 100 %	1625° (Fenner)

[1]These points are, of course, invariant only when the system is considered as a condensed system.

(9) Das binäre System Magnesiumoxyd-Silicium-2-oxyd. Olaf Andersen und N. L. Bowen. Z. anorg. Chem., 87, 283–299 (1914.)

A German translation of "The binary system $MgO-SiO_2$" (Am. Jour. Sci. (4), 37, 487–500: 1914). Reviewed under No. 8 above.

(10) **The measurement of the refractive index of a drop of liquid. Fred. Eugene Wright. J. Wash. Acad. Sci., 4, 269–279 (1914).**

The measurement of the refractive indices of irregular mineral grains measuring 0.01 mm. in diameter is best accomplished by means of the immersion method, by which the refractive indices of the mineral grain are compared with that of the liquid in which it is immersed. The measurement of the refractive index of a single drop of liquid can be accomplished by a number of different methods. The accuracy of the standard methods (with the exception of the Abbe refractometer methods) for this purpose is discussed and certain new modifications are suggested which render possible the application of such methods to a single drop of liquid. The use of a diffusing screen in front of monochromatic light sources is emphasized. A new type of hollow prism is suggested which has proved satisfactory and convenient, and with which accurate measurements (accurate to the fourth decimal place) can be made either by a method of autocollimation or by the minimum deviation method or by Gifford's method. The use of a cover of specially prepared tinfoil on a drop of liquid to be measured on the Abbe-Pulfrich crystal total-refractometer is suggested as a satisfactory method for obtaining the phenomena of grazing incidence even on a thin film of liquid. Five new methods are described for measuring the refractive index of a drop of liquid with the petrographic microscope. Of these methods, that which requires simply a plane-parallel glass plate of the high refractive index, with one edge beveled at an angle of 60°, is the simplest and most convenient; with it the refractive index of a drop of liquid can be easily measured to the third decimal place.

(11) **An occurrence of pyroxenite and hornblendite in Bahia, Brasil. Henry S. Washington. Am. Jour. Sci. (4), 38, 79–90 (1914).**

The igneous mass occurs near Maracas, in the State of Bahia, intruded into gneisses. The central part is a hornblendite and the outer a pyroxenite, both being exceptionally fresh. Complete analyses of the two are given and their relations to other occurrences are discussed. Both rocks are notable for the large amount of manganese which they contain, which is correlated with the abundance of manganese ores in this part of the State of Bahia. There is also a notable amount of copper.

(12) **Hewettite, metahewettite, and pascoite; hydrous calcium vanadates. W. F. Hillebrand, H. E. Merwin, and Fred. E. Wright. Proc. Am. Phil. Soc., 53, 31–54 (1914).**

Two apparently different calcium vanadates are described, which resemble each other very closely and have the same composition ($CaO.\ 3V_2O_5.\ 9H_2O$) when holding their maximum water-content at room temperatures. One of them, hewettite, occurs at Minasragra, Peru, and has been noticed on a single specimen from Paradox Valley, Colorado. The other, metahewettite, occurs at numerous localities in western Colorado and eastern Utah. Both minerals are sparingly soluble in water.

A third calcium vanadate, pascoite ($2CaO.3V_2O_5.11?H_2O$), is also described. This occurs with hewettite at Minasragra. It is very soluble in water.

The first and second minerals are regarded as hydrated acid hexavanadates ($CaH_2V_6O_{17}.8H_2O$), the third as a normal hexavanadate ($Ca_2V_6O_{17}.11?H_2O$).

The reasons for specific separation of hewettite and metahewettite are set forth in detail. The two minerals are so sensitive to changes in atmospheric humidity that their water-content varies within wide limits at different times of the year. The removal of all or nearly all the water does not result in breaking down of the crystal structure, and until this has occurred the water is wholly or in great part taken up again when opportunity is offered.

The importance is emphasized of bringing all minerals that behave in this way to a definite maximum water-content before analyzing them and of following carefully the course of dehydration under prescribed conditions. Detailed directions are given for such tests and for avoiding several sources of error.

Attention is also called to two fairly constant associates of metahewettite. One of these (also a constituent of carnotite ores) is a gray hydrous silicate of aluminum, trivalent vanadium, and potassium. The other is elemental selenium, the existence of which as a mineral species seems now for the first time established.

(13) Hewettit, Metahewettit, und Pascoit, Calcium Hydrovanadate. W. F. Hillebrand, H. E. Merwin, und Fred. E. Wright. Z. Kryst. (In press.)

A German translation of "Hewettite, metahewettite, and pascoite, hydrous calcium vanadates" (Proc. Am. Phil. Soc., 53, 31–54, 1914). Reviewed under No. 12 above.

(14) The ternary system: diopside–forsterite–silica. N. L. Bowen. Am. Jour. Sci. (4), 38 207–264 (1914).

The results obtained in the investigation of the three binary systems involved are first presented. The system diopside-silica shows the simple eutectic relation, as does also the system diopside-forsterite. The system forsterite-silica shows one intermediate compound, $MgSiO_3$ (clino-enstatite), unstable at its melting-point.

In the ternary system it is found that clino-enstatite and diopside form a complete series of solid solutions (monoclinic pyroxenes) and therefore have a common field. As a further consequence of this unbroken series of solid solutions there is no ternary eutectic, the lowest point of formation of liquid in the system being the binary eutectic diopside-silica.

A brief theoretical discussion of solid solution in ternary systems is given. The course of crystallization in typical mixtures of the present ternary system is described, and the value of certain lines termed three-phase-boundaries is pointed out, especially their usefulness in determining the composition of mix-crystals separating at any temperature. In considering crystallization it is shown that crystallization may proceed according to two different methods: first, that in which the liquid is, at any temperature, in equilibrium with all the crystals and all parts of the crystals occurring in it, and second, that in which the liquid is in equilibrium at any temperature only with the crystals separating at that temperature. In a general way, crystallization of the second type is favored by quick cooling.

The importance of distinguishing between the two types of crystallization is great in the present system. It is shown that the difference between the conclusions arrived at in the present work and those arrived at in an earlier investigation of the pyroxene series carried out at this Laboratory is due largely to the fact that in the earlier work crystallization of the second type occurred in many of the mixtures, whereas, if equilibrium is to be studied, crystallization of the first type must be obtained.

In the optical part of the paper the optical properties of the various crystalline phases are given. The properties of the series of monoclinic pyroxenes extending from diopside to enstatite vary continuously with composition. The artificial pyroxenes are compared with the enstatite-augites of Wahl.

In considering the bearing of the results on petrologic problems attention is called to the resorption of the olivine forsterite in the artificial mixtures and its probable relation to resorption of olivines in natural rocks. The consequences of the possible settling of crystals in a fluid magma (crystallization-differentiation) is discussed in the light of the facts known concerning the artificial mixtures.

(15) Das ternäre System: Diopsid-Forsterit-Silicium-2-oxyd. N. L. Bowen. Z. anorg. Chem., 90, 1-66 (1914).

A German translation of "The ternary system: diopside-forsterite-silica" (Am. Jour. Sci. (4), 38, 207–264: 1914). Reviewed under No. 14 above.

(16) The composition of rockallite. Henry S. Washington. Quart. J. Geol. Soc., 70, 294–302 (1914).

The paper is a chemical study of a unique ægirite granite from the islet of Rockall, north of Ireland. Only three small specimens are known, and that examined was generously given through Professor J. W. Judd by the Governors of the Imperial College of Science. A very complete chemical analysis was made, which confirms in the general features one made some years ago in England. It shows, in addition, the presence of large amounts of zirconia and ceria—the amount of the latter being next to the highest yet known for igneous rocks. By comparison with the minerals present in the rock, it is shown that these two oxides belong to the pyroxenes, and the probability is pointed out that the presence of these two oxides is characteristic of acmite as contrasted with their absence in the closely related ægirite. Further study of this point will be undertaken when material from Norway, to be furnished through the kindness of Professor Brögger, is received.

(17) The crystallographic and optic properties of magnesium and manganese pyrophosphates. Olaf Andersen. J. Wash. Acad. Sci., 4, 318–325 (1914).

Pyrophosphates of magnesium and manganese were obtained in crystals by cooling the melts of the pure substances.

The magnesium pyrophosphate ($Mg_2P_2O_7$) is monoclinic (axial ratios $a:b:c = 0.7947:1:1.0880$; $\beta = 75° \ 49'$), forming tabular crystals composed of numerous small individuals in parallel intergrowth. Forms: $c(001)$; $z(110)$; $r(\bar{1}01)$; $x(\bar{1}12)$. Colorless. Hardness about 4. Cleavage perfect after z and good after c. Density $G\left(\frac{25}{4}\right) = 3.058$. Optical properties determined under the microscope: $\gamma_{Na} = 1.615$; $\beta_{Na} = 1.604$; $\alpha_{Na} = 1.602$. Optical character positive. Axial angle $2V = 20\frac{1}{2}°$ ($2E = 33°$). Optical orientation: Plane of optic axis (010) $Bx_a = \gamma = a -$ axis.

Manganese pyrophosphate is also monoclinic, with very nearly the same crystallographic properties as the magnesium pyrophosphate ($a:b:c = 0.7834:1:?$; $\beta = 74° \ 9'$). The crystal habit is prismatic. Forms: $c(001)$; $a(100)$; $z(110)$. Color brownish pink. Hardness about 5. Cleavage perfect along z and poor parallel to c. Density $G\left(\frac{25}{4}\right) = 3.707$.

Optical properties: $\gamma_{Na} = 1.710$; $\beta_{Na} = 1.704$; $\alpha_{Na} = 1.695$.

Optical character positive. Axial angle large, estimated $2V$ = about 80°.

Optical orientation: plane of optic axes (010); $Bx_a = \gamma$; $\gamma : a = 20°$ in obtuse angle β. Pleochroism in thick cleavage pieces: α light pink; β, γ nearly colorless, with a faint yellowish tinge.

A thermal examination of mixtures of the two phosphates was undertaken. The results are stated in the following table:

Composition.		Melting-points.	Mean refractive indices.
$Mn_2P_2O_7$	$Mg_2P_2O_7$		
		° C.	
100	0	1196	1.70
75	25	1242	1.67
50	50	1286	1.65
25	75	1340	1.63
0	100	1383	1.60

Microscopic examination of the mix-crystals showed that they were homogeneous or had indication of zonal structure.

The crystallographic examination proves that the two phosphates are isomorphous. The thermal examination further shows that they are perfectly miscible in the solid state and that the system $Mg_2P_2O_7$–$Mn_2P_2O_7$ belongs to Roozeboom's Type I.

(18) The determination of the relative refringence of mineral grains under the petrographic microscope. Fred. Eugene Wright. J. Wash. Acad. Sci., 4, 389–392 (1914).

The standard methods for the determination of the relative refringence of mineral grains under the microscope are convenient and entirely adequate for ordinary purposes; but where great accuracy is required they are less satisfactory and are difficult to apply because of the eye-strain involved. A new method of two-fold oblique illumination is proposed which enables the observer to reduce the field illumination at will and thus to obviate the eye-strain. In this method two straight-edged metal stops are used, the first below the condenser and the second in the conjugate image plane of the first above the condenser. By adjustment of these stops it is possible to decrease the intensity of illumination to any extent and thus finally to exclude all light except that refracted by the individual mineral grains; conditions are then attained which are analogous to those first used by Töpler for the detection of optical inhomogeneity in glass. The sources of monochromatic light best adapted for refractive-index work with the petrographic microscope are described briefly.

(19) The optical character of the faint interference figure observed in high power objectives between crossed nicols. Fred. Eugene Wright. J. Wash. Acad. Sci., 4, 301–309 (1914).

The appearance of a faint, apparently uniaxial interference figure in a high-power microscope objective between crossed nicols is a matter of common observation. The first correct explanation of the phenomenon was given by Rinne in 1900, but no explanation of the apparently optically positive character of this interference figure has heretofore been given. In the present paper the explanation of this conversion of an isotropic substance, like glass, into an apparently uniaxial optically positive substance is presented in some detail and rendered evident both by a series of experiments and by theoretical computation. The plane of vibration of the incident plane-polarized light waves is rotated at the steeply inclined surfaces of the lenses in the objective. The amount of the rotation at a particular point is dependent on the inclination and azimuth of the surface of the glass with respect to the plane of the analyzer, the refractive index of the glass, and the wave-length of light employed. The combination of these factors gives rise to the phenomena observed.

(20) A new half-shade apparatus with variable sensibility. Fred. Eugene Wright. J. Wash. Acad. Sci., 4, 309–313 (1914).

The apparatus consists of two strips of plane parallel glass cemented to the two sides of a 45° total reflecting prism in such a manner that the ends of the strips extend 6 or 8 mm. beyond one end of the prism. The hypothenuse face of the prism is mounted on an axis supported in a brass cylinder in such a way that the common edge of the glass plates is normal to the axis of rotation. If the glass plates be observed between crossed nicols, the plane of vibration of the light-waves transmitted through them can be rotated through a small angle by turning the device about the axis, the angle of rotation of the plane of vibration of the light-waves in the one plate being equal but opposite to that in the second glass plate. This device furnishes a simple and inexpensive method for constructing an effective half-shade apparatus with variable sensibility.

(21) A new dip chart. Fred. Eugene Wright. J. Wash. Acad. Sci., 4, 440–444 (1914).

In both structural and mining geology the problem frequently arises to determine the direction, on a given vertical section, of the trace of a bed or plane of known dip and strike. The chart proposed in this paper enables the observer to solve the problem directly with an accuracy of about 0.1°. The chart is so constructed that the equation of which it is the graphical solution is represented with as little distortion as possible.

(22) The optical properties of roscoelite. Fred. Eugene Wright. Am. Jour. Sci. (4), 38, 305–308 (1914).

The optical data were obtained on unusually good material, kindly loaned by Dr. W. F. Hillebrand for the purpose. Color, olive green. Luster, splendid, almost submetallic and bronze-like. Cleavage, 001, perfect; 010, good. Hardness between 2.5 and 3. Pleochroism, γ = green brown, β = olive green, a = olive green. Absorption, fairly strong, $\gamma > \beta > a$. Refractive indices, $\gamma = 1.704 \pm 0.003$, $\beta = 1.685 \pm 0.003$, $a = 1.610 \pm 0.003$. Birefringence strong. $2E_{Na} = 42$ to $69°$; $2E_{Li} = 34$ to $60°$. Axial dispersion strong $2E_v > 2E_r$. Optical orientation, $b = \gamma$, $a : \beta = 0°$ or a small angle not over 4°.

(23) The simultaneous crystallization of calcite and certain sulphides of iron, copper, and zinc. A crystallographic study. H. E. Merwin. Am. Jour. Sci. (4), 38, 355–359 (1914).

The study of three occurrences of the sulphides of iron and zinc has established with certainty the deposition of marcasite, and with strong probability the deposition of wurtzite contemporaneously with calcite. The marcasite is definitely oriented with regard to the calcite and also the accompanying pyrite. A close similarity between the crystallographic elements of pyrite and marcasite is shown.

(24) The thermal dehydration of stilbite, thaumasite, and the hydrates of magnesium sulphate and copper sulphate. H. E. Merwin. J. Wash. Acad. Sci., 4, 494–496 (1914).

The method of locating sharp changes in the rate of dehydration of hydrates by heating for definite periods at regularly increasing temperatures is applied to substances which readily lose water in dry air at ordinary temperatures. Two new hydrates of magnesium sulphate have thus been identified, and stilbite has been shown not to be a definite hydrate.

(25) Equations containing only one unknown constant to represent the parabola, the rectangular hyperbola, and certain exponential curves. H. E. Merwin. J. Wash. Acad. Sci., 4, 467–469 (1914).

The parabola is represented by

$$\frac{x_2-x}{y_2-y}=\frac{x_2-x_1}{y_2-y_1}+C\,(y-y_1)$$

the rectangular hyperbola by

$$\frac{x_2-x}{y_2-y}=\frac{x_2-x_1}{y_2-y_1}+C\,(x-x_1)$$

and $\quad \dfrac{x_2-x}{y_2-y}=\dfrac{x_2-x_1}{y_2-y_1}C^{x-x_1}$ and $\dfrac{x_2-x}{y_2-y}=\dfrac{x_2-x_1}{y_2-y_1}C^{y-y_1}$ are exponentials.

(26) The mode of formation of certain gneisses in the Highlands of New Jersey. Clarence N. Fenner. J. Geol., 22, 594–612; 694–702 (1914).

The paper deals with certain geological phenomena which have been observed in an area of ancient crystalline rocks in northern New Jersey, and discusses the manner in which the structures in question have originated.

The manner of action of the processes is considered, not only from the geological side, but also from physical and chemical standpoints. A description is first given of the structural relations of the gneisses as observed in the field, and evidence is presented leading to the belief that at this locality the foliation of the gneisses can not well be attributed to the squeezing-out of a partly differentiated magma or to the shearing and recrystallization of a solidified rock, but that its origin must be looked for in a process involving the injection of a thinly fluid granitic magma between the layers of an original rock of a laminated character. Evidence is found which indicates that the process of injection was carried out in a most quiet and gradual manner, and possessed many of the characteristics of a substitution of the original material by the magmatic solution rather than the features of a violent intrusion. The observed relations are very similar to those which certain French geologists have described under the name of *lit-par-lit* injection, and the mode of operation is believed to have been essentially the same.

Certain features which were observed in the gneisses imply properties of the magma which at first sight do not appear mutually consistent. Thus the degree of viscosity implied by the presence of thinly tabular sheets of inclusions within the granite, standing nearly upright and unsupported except by the magma on either side, does not harmonize with the facility with which magmatic material has been transfused into the original rock. In trying to reconcile these features inquiry has been directed toward a consideration of certain of the physical and chemical properties of magmatic solutions. The question of the critical temperatures of volatile substances is discussed in its bearing upon their condition within the magma. Further, the question of the possibility of a viscous magma penetrating the pores of the wall-rock is considered and the problem of a possible differentiation of a magma when injected between the layers of a rock in a multitude of adjacent streams is taken up. Certain inferences are drawn regarding the operation of such processes and the conclusion is reached that under such conditions of injection as prevailed at this locality, the advance of the main body of magma would be preceded by that of a more dilute portion, which would be able to impregnate the wall-rock with facility and initiate processes of transformation and solution which the more concentrated body following would carry farther toward completion.

(27) The analcite basalts of Sardinia. Henry S. Washington. J. Geol., 22, 742–753 (1914).

At Monte Ferru and elsewhere in Sardinia lavas occur which show in thin section small round isotropic areas, resembling sections of leucite, so that the rocks have been commonly held to be leucite basalts. A careful study and three chemical analyses of these rocks, collected during the author's trip to Sardinia in 1905 for the Carnegie Institution of Washington, show that the supposed leucite is in reality the hydrous soda mineral analcite, and that it is of primary origin. Comparison with similar rocks from other regions indicates that some so-called leucitic rocks are in fact analcite-bearing, and that rocks containing primary analcite in well-developed crystals are much more abundant than has been supposed. Analyses are also given of the augite and olivine which form nodules in one of the lavas, the optical study of which is to be taken up later.

(28) I Basalti Analcitici della Sardegna. Henry S. Washington. Boll. Soc. Gool. Ital., 33, 147–167 (1914).

An Italian translation of "The analcite basalts of Sardinia" (J. Geol., 22, 742–753: (1914). Reviewed under No. 27 above. An appendix is added which gives a brief outline of the quantitative classification of igneous rocks.

(29) The Stokes method for the determination of pyrite and marcasite. E. T. Allen and J. L. Crenshaw. Am. Jour. Sci. (4), 38, 371–392 (1914).

The Stokes method for determining pyrite and marcasite, alone or in mixtures, depends on the estimation of the iron dissolved when the finely ground and purified sulphide is treated with a boiling standard solution of ferric alum. The *same* pyrite or marcasite gives very constant values and the influence of each in mixtures is additive, *i. e.*, there exists a linear relation between the iron dissolved and the composition of the mixture. The sum of the errors usually amounts to about 1 per cent, reaching a maximum of 2 per cent. There are two important sources of error. First, there must be a sufficient excess of the sulphide, which is many times greater (7 to 15) than the amount required by theory. With such an excess the percentage of the surfaces remains on the average nearly the same as the percentage by weight, the basis on which the mixtures are made up. About 1 gram is sufficient for 250 c.c. of the standard solution. Secondly, the marcasite has a characteristic tendency to flocculate and thus reduce its reacting surface. This difficulty may be avoided by shaking the reacting mixture with pure quartz and beads until the lumps of the powder are thoroughly disintegrated. *Different specimens* of pyrite and marcasite give with the Stokes reaction values which differ somewhat. The differences are due in some cases, if not in all, to the presence of impurities. It is unfortunate that small quantities of impurities which will reduce ferric iron or give up iron to the solution exercise a serious influence. It is therefore not always possible to decide between a natural pyrite and a pyrite containing several per cent of marcasite by the Stokes reaction alone, nor to determine accurately the percentage of each in a natural mixture. In an investigation on the conditions of formation of pyrite and marcasite, this method has been very useful.

The results with the Stokes method plainly indicate that each mineral behaves in a mixture of the two just as it does alone; each appears to reduce a quantity of solution which is proportional to its surface; and each appears to reduce the solution at practically the same rate. The rates at which the sulphides are decomposed is quite different for the two minerals, because more of marcasite than of pyrite is required to reduce a given quantity of ferric iron. The ratio of these rates is not far from 1: 2.5.

That ferric sulphate dissolves from pyrite a smaller quantity of iron than it does from marcasite means simply that more reduction is effected by sulphur in the case of pyrite; in other words, that more of the sulphur in pyrite is oxidized. Stokes considered only the relation of p, the percentage of sulphur oxidized, to y, the percentage of pyrite in the sulphide mixture. We have shown that this curve is a hyperbola. This characteristic behavior of pyrite and marcasite towards oxidizing agents is probably general. It has been found by other observers that nitric acid and hydrogen peroxide both oxidize more of the sulphur in pyrite under the same conditions.

(30) Stokes Methode zur Bestimmung von Pyrit und Marcasit. E. T. Allen und J. L. Crenshaw. Z. Anorg. Chem., 90, 81–106 (1914).

A German translation of "The Stokes method for the determination of pyrite and marcasite" (Am. Jour. Sci. (4), 38, 371–392: 1914). Reviewed under No. 29 above.

(31) Effect of temperature and acidity in the formation of marcasite (FeS_2) and wurtzite (ZnS); a contribution to the genesis of unstable forms. E. T. Allen and J. L. Crenshaw. Microscopic study by H. E. Merwin. Am. Jour. Sci. (4), 38, 393–431 (1914).

Our former results on the genesis of marcasite and wurtzite have been reinvestigated, the former conclusions have been confirmed, and new data

determined. The specific influence of acidity and alkalinity on the crystal form of the sulphides investigated has been much more rigorously demonstrated. Only from acid solutions were the unstable forms obtained. The sulphides were prepared by the action of hydrogen sulphide on acidic solutions of zinc salts and by hydrogen sulphide and sulphur on acidic solutions of ferrous salts. The unstable forms were usually mixed with the corresponding stable forms, viz, sphalerite and pyrite, and the composition of the mixtures was determined, approximately for the zinc sulphides, by microscopic estimation; and within 1 to 2 per cent by the Stokes method for the iron disulphides.

As previously found, the higher the maximum temperature of experiment, other conditions remaining unchanged, the greater the quantity of the stable form, pyrite or sphalerite, obtained in the product.

As previously concluded, the higher the percentage of acid in the solution, other conditions remaining unchanged, the greater in general the quantity of the unstable sulphide, marcasite or wurtzite. The relation between the percentage of marcasite and the average acidity was practically linear for maximum temperatures of 200° and 300° C. There are also indications of a similar relation in the case of wurtzite. In the case of wurtzite, however, the final acid was found to be the determining factor, since at 300° and 325° C. wurtzite appears to change into sphalerite when heated with sufficiently dilute acid. The temperature-acid field in the case of zinc salts may be divided by two boundary curves into three subfields: a high-acid field in which only wurtzite is obtained, a low-acid field where only sphalerite is obtained, and an intermediate field where mixtures of the two are obtained.

No crystalline zinc sulphide could be obtained from the hydrochloric-acid solutions, but the iron disulphides were crystallized from them, and always contained much more marcasite for an equivalent quantity of acid, *i. e.*, hydrochloric acid has a much greater influence on the crystal form than an equivalent quantity of sulphuric acid, which should be the case if the hydrogen ion concentration were the real determining factor.

The acid concentration required to give rise to pure marcasite or pure wurtzite falls with the temperature and is close to neutrality for marcasite at ordinary temperature, and probably so for wurtzite.

Several conditions other than acidity and temperature were varied in the formation of wurtzite, where the process was necessarily more complicated; these were zinc concentration, addition of sodium sulphate to the solutions, and hydrogen-sulphide pressure. None of these had any influence, except as they affected the acidity.

At temperatures of 25° and 200° C. from sulphuric-acid solutions and at 300° C. from hydrochloric-acid solutions we obtained a product containing 95 per cent of marcasite comparable with the purest natural marcasite we have had in our hands. Since this determination depends on the quantity of iron dissolved from the mineral under definite conditions, and different natural specimens vary somewhat, it may be that this product is pure synthetic marcasite.

Some new data on the genesis of the natural minerals are cited.

(32) Einfluss von Temperatur und Säuregrad auf die Bildung von Marcasit (FeS_2) und Wurtzit (ZnS); einen Beitrag zur Enstehung instabiler Formen. E. T. Allen und J. L. Crenshaw. Mikroskopische Studien von H. E. Merwin. Z. anorg. Chem., 90, 107–149 (1914).

A German translation of "The effect of temperature and acidity on the formation of marcasite (FeS_2) and wurtzite (ZnS): a contribution to the genesis of unstable forms" (Am. Jour. Sci. (4), 38, 393–431: 1914). Reviewed under No. 31 above.

(33) **Thermo-element installations, especially for calorimetry.** Walter P. White. J. Am. Chem. Soc., 36, 1856–1868 (1914).
(34) **Potentiometers for thermo-electric measurements, especially in calorimetry.** Walter P. White. J. Am. Chem. Soc., 36, 1868–1885 (1914).

These two papers describe a type of auxiliary installation for thermo-elements which in high-temperature measurement and other work of moderate precision is valuable for its convenience, quickness, and comprehensiveness, and which is also capable of the very high precision often desired for calorimetry.

When a thermo-element is used with its two ends at nearly the same temperature, a condition easily provided in calorimetry, the relative precision required in the electrical measurement falls to a value no greater than that desired in the temperature reading, and the most serious errors ordinarily affecting the electrical thermometer practically disappear.

The absolute electrical precision required is also comparatively low. With a convenient and easily made copper-constantan multiple thermo-element of 24 couples, 0.0001° C. corresponds to 0.1 microvolt.

The satisfactory attainment of a precision of 0.1 microvolt demands two, and only two, special electrical instruments. The first is an arrangement for eliminating the effect of parasitic thermal electromotive forces. A common copper knife-switch will perform this service admirably. The second special requirement is an appropriate potentiometer, that is, one reliable to 0.1 microvolt.

The slide-wire and Feussner potentiometers of 1 volt range or more now in common use are not thus reliable, and are otherwise unsuited for thermo-element work. Split-circuit potentiometers are satisfactory in this and all other important respects, and so are combination potentiometers, or potentiometers having two otherwise separate, very simple instruments in series in the same galvanometer circuit. A very low-priced split-circuit potentiometer is on the market; and the combination potentiometer, on account of its mechanical and electrical simplicity, is an easy instrument to build to order.

The potentiometer system, either with or without the thermo-element, is especially suited to simultaneous measurements of different and differently varying electromotive forces. Its convenience for such measurements can be increased by using a few pieces of hard-rubber sheet as stops for the dial switches, and still further increased by arranging a double potentiometer, with duplicate dials. One effective form of double potentiometer, which employs a master-switch, can be arranged at the cost of a few knife-switches and very little labor. An especially suitable instrument to arrange in this way is the combination potentiometer, all of whose dial switches are single, and free from contact resistance error.

Another convenience especially easy to obtain with the thermo-element-potentiometer system is the power to take the last two figures of any reading directly from the galvanometer scale. It increases speed, simplifies manipulation, diminishes errors, and gives calorimetric data in a form specially convenient for further treatment.

For high-temperature measurements and much other thermo-element work not calorimetric, though the required precision may often be less, most of the features above described are desirable, especially the facility for simultaneous and direct readings.

(35) **Leakage prevention by shielding, especially in potentiometer systems.** Walter P. White. J. Am. Chem. Soc., 36, 2011–2020 (1914).

An insulation resistance of 5,000 megohms or more is often necessary to prevent serious disturbance of thermo-electric measuring systems from stray portions of power or lighting currents, and the frequently more sensitive

resistance-measuring system is of course in greater danger still. All such trouble is absolutely prevented by an equipotential shield, which is merely a connected system of metal plates, wires, etc., which interposes itself at every point of solid contact between the measuring system and external bodies. This shield need not be, and preferably should not be, "earthed."

Slight modifications of this shield are also useful in electric furnaces, in the measurements upon power circuits, and within the potentiometer circuit itself.

These arrangements are easy to install, most of them require no subsequent attention, and all are easily tested.

(36) Thermo-elements of precision, especially for calorimetry. Walter P. White. J. Am. Chem. Soc., 36, 2292–2313 (1914).

Inhomogeneity, once a serious foe to precision in thermo-elements, and still often supposed to be such, can without difficulty be rendered practically negligible in copper-constantan thermo-elements used for any precision up to 50 parts per million. Such thermo-elements, accordingly, may, except for imperfect insulation, easily preventable, be free from all appreciable errors other than those (such as incomplete depth of immersion) which are possible with all thermometers. To attain this freedom from error the wire used must be tested, and the essential though easily satisfied requirements peculiar to a thermo-electric system must be observed. These requirements this paper attempts to consider in detail, and it also describes simple but important details regarding the operations of construction, insulation, inclosure, calibration, etc., of the thermo-elements.

Constantan wire for thermo-elements has been so far improved that continuous lengths are frequently obtainable which vary (in electro-motive force against copper) less than 0.0002, making sensitive thermo-elements with errors usually less than 20 per million.

The testing of wire enough for a thermo-element of maximum sensitiveness takes but an hour or two, with simple apparatus.

On account of the ease with which thermo-elements can be constructed, the more sensitive combination of several couples is generally preferable to a single couple, even for cruder measurements.

(37) Easy calorimetric methods of high precision. Walter P. White. J. Am. Chem. Soc., 36, 2313–2333 (1914).

In the calorimetric method of mixtures, a precision approaching or reaching 0.1 per mille, though somewhat unusual, is often desirable, and is ordinarily not difficult to attain with appropriate apparatus. Its attainment is especially easy with a two-calorimeter installation, which secures the convenience and high precision of differential thermo-electric temperature measurement. This is the only advantage of the two-calorimeter arrangement; the diminution of heat-loss error, often counted an advantage, turns out upon examination to be largely illusory. By abandoning the twin calorimeters previously used to get this supposed advantage, and using for the comparison calorimeter a vacuum-jacketed flask, there is a gain in convenience and precision. A special thermo-element combination renders the necessary temperature observations as simple as with the twin arrangement. A completely inclosing jacket of uniform temperature is necessary for this method, but this is no loss, for such a jacket proves to be necessary for highest precision with any other method. This method is quite as effective with two jackets, one around each calorimeter, and therefore with adiabatic methods.

Efficient complete jackets can be very easily realized according to several methods, which are described.

As compared with others, the present method is specially advantageous for observations of great absolute precision and wherever it is desirable to secure the advantages which the thermo-electric system possesses in the way of rapidity and of facility in making varied observations.

(38) The calculation and comparison of mineral analyses. C. E. Van Orstrand and Fred. E. Wright. J. Wash. Acad. Sci., 4, 514–525 (1914).

In this paper the nature of the errors in a chemical analysis is discussed in detail. General mathematical equations are given for the least-square adjustment of the data of a mineral analysis; these equations express in concise form all possible adjustments dependent upon averages. The importance of assigning or preferably of determining the weights of the observed data is emphasized. A method for the detection of the systematic errors of an analysis is given and illustrated by examples. The various different methods which have been suggested for the adjustment of chemical analyses are considered in the light of these equations and the significance of each method is thereby ascertained. The general conclusion is reached that for most purposes the established method of direct comparison of the weight percentages of chemical analyses is sufficient.

(39) A simple method for the accurate measurement of relative strain in glass. Fred. Eugene Wright. J. Wash. Acad. Sci., 4, 594–598 (1914).

The method consists essentially in measuring between crossed nicols the path-difference of plane polarized light monochromatic waves from an intense mercury source ($546\mu\mu$) on glass cubes of uniform thickness. The path-difference is read off directly on a graduated double combination quartz wedge described in 1908 by the writer. With a wedge ground especially to show slight path-differences it is possible to detect and measure path-differences of less than $1\mu\mu$. This degree of precision is sufficient for all practical purposes. The conversion of path-differences into the corresponding mechanical units which produce them is obtained by direct experiment with the particular glass under investigation.

(40) A new crystal-grinding goniometer. Fred. Eugene Wright. J. Wash. Acad. Sci., 5, 35–41 (1915).

Accurately oriented crystal plates and faces are often desirable in crystallographic and optical work. To meet this need several different crystal-grinding goniometers have been constructed. The present precision instrument was built in the workshop of the Geophysical Laboratory, and with it oriented crystal plates can be ground and polished within 1′ of the required orientation. The crystal can be oriented either optically or crystallographically. In the design and construction of the grinding goniometer special care has been taken to produce a mechanically rigid and precise instrument. The grinding goniometer has been in constant use for several months and has proved to be convenient, accurate, and well adapted for the particular purposes for which it is intended, namely, to grind crystal faces on crystals which are to be measured at high temperatures and pressures; also to grind oriented crystal plates and prisms for optical measurements.

(41) Spring deposits at Sulphur Springs, Arkansas. C. E. Siebenthal. Microscopic study by H. E. Merwin. J. Geol., 23, No. 1 (1915).

Analyses of water and sediments from springs, and microscopic study of sediments, indicate that sulphides of iron, zinc, copper, and lead are carried in solution, and that iron sulphides, especially, are being deposited in both amorphous and crystalline states where the waters come to the surface. The bearing of these observations upon the genesis of the sulphide deposits in the Mississippi Valley is discussed.

(42) A significant instance of galvanometer instability. Walter P. White. Phys. Rev. (2), 3, 491–492 (1914).

A radial-field moving coil galvanometer, very free from ordinary tremors, was much deflected by various shocks occurring within the building, and this effect disappeared whenever the supporting shelf was fastened to the wall with sufficient firmness. Apparently, a slight tipping of the shelf was to blame. At any rate, if there had also been any visible tremors of the galvanometer coil, these would have been supposed to be responsible for the trouble. It follows that in other cases where tremors *are* present, and are supposed to cause troublesome deflections, the real trouble may be due to some other, more easily removable cause.

(43) Measurements of the extraordinary refractive index of a uniaxial crystal by observations in convergent light on a plate normal to the optic axis. H. E. Merwin. J. Wash. Acad. Sci., 4, 530–534 (1914).

From the following microscopical measurements on a plate normal to the optic axis, an accurate calculation of the maximum double refraction of a uniaxial mineral can be made: (1) the optical character, (2) the thickness, (3) the index of refraction, ω, (4) the angular diameter of one of the light or dark rings observed in convergent polarized light. The method involves the calculation of the refractive index of the extraordinary wave along its path to the ring, and the use of this value in the general equation of the index ellipsoid.

(44) The ternary system $CaO–Al_2O_3–SiO_2$. G. A. Rankin; with optical study by Fred. Eugene Wright. Am. Jour. Sci. (4), 37, 1–79 (1915).

The purpose of this investigation was to ascertain the stability relations in the ternary system $CaO–Al_2O_3–SiO_2$, not only from a purely scientific point of view, but also from the bearing of the facts thus discovered upon a number of geological inquiries and upon the problem of the nature of portland-cement clinker. Many papers on this general topic have, of course, already been published, but the work recorded is in the main fragmentary and of little avail in settling the large general questions involved. The present investigation aims to treat the system rather completely, to ascertain the equilibrium relations in the system. To this end all the possible compounds which are found in dry melts of the three oxides CaO, Al_2O_3, SiO_2 have been determined, in especial those which are stable at the liquidus; this involves measurements of the respective melting-points or dissociation temperatures, and the determination of the invariant points, boundary curves (monovariant systems), and fields of stability (divariant systems) of the various compounds.

This paper contains a summary record of the work performed; it is the first thoroughgoing attempt, so far as known, to determine all the compounds, both binary and ternary, of CaO, Al_2O_3, SiO_2, and the mutual relations of these compounds, many of which have, of course, previously been made synthetically by others. The data obtained are made use of in a discussion of the nature and constitution of portland-cement clinker and of the formation of certain natural minerals from the magma.

Three papers dealing with this sytem have already been published from this Laboratory. The first two dealt with the binary systems,[1] while in the third[2] provisional locations were assigned to ternary quintuple points and boundary curves and the new relations applied in a discussion of the constitution of portland-cement clinker. In the present paper a more exact location is given

[1]The lime-silica series of minerals. A. L. Day, E. S. Shepherd, and F. E. Wright. Am. Jour. Sci. (4), 22, 265 (1906); reviewed in Year Book No. 5, p. 181. The binary systems of alumina, with silica, lime, and magnesia. E. S. Shepherd, G. A. Rankin, and F. E. Wright. Am. Jour. Sci. (4), 28, 293 (1909); reviewed in Year Book No. 8, p. 104.

[2]Preliminary report on the ternary system $CaO–Al_2O_3–SiO_2$. A study of the constitution of portland-cement clinker. E. S. Shepherd, G. A. Rankin, and F. E. Wright. Jour. Ind. Eng. Chem., 3, 1–43 (1911); reviewed in Year Book No. 9, p. 102.

for the eutectics, quintuple points, and boundary curves, together with the corresponding temperatures. Owing to the large amount of data it will not be possible to give in a paper of this nature more than the mean values obtained from a large number of determinations of the various points. But complete tables of data and a much more complete discussion of methods and apparatus and of the results obtained will be given in a later monograph.

(45) Das ternäre System: $CaO–Al_2O_3–SiO_2$. G. A. Rankin; mit optischen Studien von Fred. Eugene Wright. Z. anorg. Chem. (In press.)

A German translation of "The ternary system $CaO–Al_2O_3–SiO_2$" (Am. J. Sci. (4), in press, 1914). Reviewed under No. 44 above.

(46) Determination of cuprous and cupric sulphide in mixtures of one another. Eugen Posnjak. J. Am. Chem. Soc., 36, 2475–2479 (1914).

The reaction between cuprous sulphide and silver nitrate was confirmed in accordance with the equation

$$Cu_2S + 4AgNO_3 = Ag_2S + 2Ag + 2Cu(NO_3)_2$$

It was found that silver sulphide only, and no metallic silver, is formed by the reaction between cupric sulphide and silver nitrate, the equation for this reaction being

$$CuS + 2AgNO_3 = Ag_2 + Cu(NO_3)_2$$

Based on the difference between these reactions, a method is given in this paper for the determination of cuprous and cupric sulphide in mixtures of the two. The mixture is treated with silver nitrate and from the product the metallic silver is extracted by means of ferric nitrate. The amount of cuprous sulphide is calculated from the metallic silver, while the cupric sulphide is calculated from the difference between the silver in the silver sulphide and the metallic silver.

In mixtures containing the constituents in any proportion whatever, the method was shown to be accurate within 1.5 per cent.

(47) Measurements of refractive indices on the principal optical sections of birefracting minerals in convergent polarized light. Fred. E. Wright. J. Wash. Acad. Sci., 4, 534–542 (1914).

On a given principal optical section of a birefracting mineral two of its three principal refractive indices can be measured directly by the immersion method. In the present paper several methods are considered for determining, on the given section, the third refractive index of the mineral by means of the phenomena observed in convergent polarized light. Mathematical equations are derived which enable the observer to compute accurately the required refractive index. Incidentally the exact thickness of the mineral section and also the optic axial angle of the mineral can be computed by these methods.

(48) Babingtonite from Passaic County, New Jersey. Clarence N. Fenner. J. Wash. Acad. Sci., 4, 552–556 (1914).

The mineral babingtonite [$(Ca, Fe, Mn)SiO_3 + Fe_2(SiO_3)_3$] is a rare species, which has been found in few localities, and generally in very small crystals. During the past summer the writer collected a small quantity of a mineral at a basalt quarry at Great Notch, Passaic County, New Jersey, associated with quartz, prehnite, zeolites, etc., which upon detailed examination has been found to correspond to babingtonite. In addition to the rarity of the species the chief feature of interest was the fact that the mineral was found as the last remnants of crystals which had previously occupied cavities or casts of large size among the associated minerals. These casts have long been familiar to mineralogists and have been a source of much speculation. From their

dimensions it is apparent that some of the original babingtonite crystals attained a length of 6 to 8 inches. The deposition and subsequent removal of the mineral shows that the conditions of chemical stability were satisfied for a brief period only in the history of the deposits.

(49) Additional notes on babingtonite from Passaic County, New Jersey. Clarence N. Fenner. J. Wash. Acad. Sci., 4, 599-605 (1914).

After the appearance of the first article on babingtonite, the localities of discovery were revisited and considerable new material was collected bearing upon the question of the original minerals of the cavities. The results are presented in the second paper. They may be summarized as follows: Both babingtonite and anhydrite were originally present in the deposits and both have been removed to a large degree, leaving cavities which outline the shape of the original crystals. In some instances, the geometric form of the two was so similar that the nature of the original mineral can not be decided from the casts alone. Babingtonite, however, seems to have shown a tendency to develop in a rather tabular shape, and cavities of this kind, especially when showing the projection of many thin laminæ, are regarded as more probably due to the latter mineral. The various rectangular cavities seem sufficiently explained by the discovery of these two minerals.

Other cavities of lozenge-shaped section are of more doubtful origin. The most probable explanation appears to be to regard them as due to babingtonite of somewhat different development from the first, but the evidence at hand is not yet sufficient to decide definitely upon this point.

DEPARTMENT OF HISTORICAL RESEARCH.*

J. Franklin Jameson, Director.

The following report, the ninth annual report of the present Director, covers the period from November 1, 1913, to October 1, 1914. The regular staff of the Department has continued without change during the year. Professor William I. Hull of Swarthmore College, Professor Frank A. Golder of the Washington State College, and Dr. Francis S. Philbrick of New York have assisted the Department in work in Europe. Rear-Admiral Alfred T. Mahan, U. S. N., retired, has accepted an engagement to assist the Department for six months in the capacity of Research Associate, but does not begin his term of service until November 1, 1914.

From last November until September 1, Mr. Leland was in Paris, continuing his work there until, on the date named, it seemed plain, archives being closed and an investment of the city by the Germans being immediately expected, that the work could not be carried on further. Mr. Leland had been disposed, largely on account of copyists dependent upon his payments, to keep on with his work as long as conditions permitted its maintenance, and had done so with great coolness and good judgment, but on the date named found that it was impossible to continue useful service longer, and with some difficulty effected his return to the United States. It had been expected, before the European war broke out, that he would return in November. Only a small part of the work for which he went to Paris remains uncompleted. Miss Davenport, except for a brief period of vacation, has remained at work in London, but, on the advice of officials of the American embassy, returns to this country in October, her present work in London having been so nearly completed that the last details can be finished for her by others.

The Department has continued to occupy the same quarters as in the preceding year, in the Woodward Building in Washington. In the middle of June, as usual, its headquarters were removed to North Edgecomb, Maine, where the office work proceeded until the middle of September.

Statements respecting the general plans of the Department and the purposes which its operations are intended to subserve have been made in former reports. Briefly expressed, the main purpose of the Department is to serve the interests of present and future makers of historical monographs and general histories, by providing aids belonging to one or the other of two main classes—either books which show the inquirer

*Address: 1140 Woodward Building, Washington, D. C. (For previous reports see Year Books Nos. 3–12).

the existence and location, or assist him in the use, of bodies of historical sources, or books which themselves present in proper scientific form the full text of important historical materials. Thus the publications of the Department fall naturally into two classes, the one that of reports, aids, and guides, the other that of textual publications of documents. It has been customary in these annual reports to consider, successively, first the work of the past year, in respect to each of these two classes of publications and in respect to the miscellaneous activities of the Department, and then the plans for the ensuing year, under the same three headings.

WORK OF THE PAST YEAR.

REPORTS, AIDS, AND GUIDES.

Two volumes have been published for the Department during the year. The first, issued in May, Publication No. 90 B, is entitled "Guide to the materials in London archives for the history of the United States since 1783," a volume of 642 pages, prepared chiefly by Dr. Charles O. Paullin, now a member of the staff of the Department, and Dr. Frederic L. Paxson, professor of American history in the University of Wisconsin. Certain parts of the volume were, for reasons set forth in a previous report, prepared by Professor Charles E. Fryer of McGill University, and by Mr. David W. Parker, now a member of the staff of the Archives of the Dominion of Canada. After a brief introduction the volume takes up successively the Foreign Office papers for the period 1783–1860, and those of the Home Office, War Office, Colonial Office, Privy Council, House of Lords, Admiralty, Audit Office, Board of Trade, Customs Department, General Post Office, High Court of Admiralty, and Treasury (most of these now preserved in the Public Record Office in London), and the manuscripts of the British Museum. Under each of these heads the compilers have described, as well as it can be done in brief space for materials so enormous in bulk, the manuscript material for American history of the period from 1783–1860, which are contained in these respective collections. The largest sections are those relating to the Foreign Office Papers, Colonial Office Papers, Admiralty Papers, and British Museum manuscripts. In most of these collections the official rule is that the records are open to public inspection to the end of the year 1837 only; but special permission to extend the researches to 1860, and in a few cases to a later date, was granted to our investigators. It is believed that the book will be an indispensable manual for all those who labor upon the history of the relations between England and the United States since American independence, and that it will do much good in permitting more thorough study of those relations, which surely are among the most important topics of modern history.

The second book, published in July, is the second volume of Professor Charles M. Andrews's "Guide to the materials for American History, to 1783, in the Public Record Office of Great Britain," being Volume II of Publication No. 90 A. With this volume Dr. Andrews concludes a long period of service to the Carnegie Institution of Washington and to investigators of our colonial and Revolutionary history, a period which began in 1903, and, continued from time to time in subsequent years, as he has been able to secure freedom for such work, resulted first in the "Guide to the manuscript materials for the history of the United States to 1783, in the British Museum, in minor London archives, and in the libraries of Oxford and Cambridge," published by the Institution in 1908, and then in the two volumes on the materials in the Public Record Office, published respectively in 1912 and 1914. It is seldom that a scholar of such eminence has been persuaded to devote so much time to a task so exacting and so arid as the making of these inventories, and all students of American colonial and Revolutionary history are under great obligations to Dr. Andrews for the service he has so ungrudgingly rendered to them. Professor Andrews's last preceding volume having dealt with the State Papers, Foreign and Domestic, Colonial and Miscellaneous, the present book, the final volume of our London series, a book of 427 pages, deals with what are technically called Departmental and Miscellaneous Papers, as distinguished from State Papers properly so called. Its successive sections treat of the Admiralty Papers, those of the Audit Office, the Declared Accounts, the Lord Chamberlain's Papers, those of the Commissariat, Custom House, Postmaster General's Office, Treasury, Treasury Solicitor, War Office, High Court of Admiralty, and modern Board of Trade, and of certain special collections—Manchester, Cornwallis, Shaftesbury, Rodney, and Chatham papers. The most extensive sections are those which deal with the papers of the Admiralty, Treasury, War Office, and the High Court of Admiralty. Each section consists of valuable introductions upon the history and business of the office which produced the papers, or to which they came in the course of administration, and of lists and descriptions of documents relative to American history which may be found in each section.

The work performed by Mr. Leland and his assistants, from November to July, toward preparation of the Guide to the materials for American history in the archives and libraries of Paris, consisted in the examination of something more than a thousand volumes and cartons of manuscripts, and 174 maps. This work was performed in a variety of repositories. In the Archives Nationales more than 300 volumes were examined, besides the maps. More than 300 volumes and cartons were in the archives of the Colonies, either in the collection still retained at the ministry or in that which has been recently transferred to the Archives Nationales; these were mostly in the series

relating to Santo Domingo and Martinique. About 250 volumes were in the archives of the Ministry of Foreign Affairs, mostly in the sections Angleterre, Espagne, Russie, and Etats-Unis of the division called "Correspondance Politique." A considerable number of volumes was also examined at the Bibliothèque Nationale and other libraries, practically completing the work in Parisian libraries. A small amount of work in the archives remains still to be performed, and it was Mr. Leland's hope that he and his assistants might be able to finish this work, and thus complete his long-continued task, before the end of November. But at the outbreak of the war M. Doysié, his indispensable chief assistant, was obliged to join the army. The Archives Nationales were closed, reopened, and again closed. The archives of the ministries were, according to annual custom, closed for the month of August; at the end of that time, when investment of Paris by the German army seemed to be undoubtedly impending, it was understood that these ministerial archives would not be reopened on the first of September. On that date Mr. Leland left Paris, with regret that the small remainder of this task could not be completed, but with the knowledge that much work upon the manuscript of his book could be carried on in Washington while waiting for the conclusion of the war, and with the expectation of returning to Paris immediately after that event, and bringing his undertaking there to a close. It has been carried on, at the last, under great difficulties, which were surmounted, so far as was possible, with a degree of courage and skill which calls for special recognition.

From May, when Mr. R. R. Hill was at length free from his duties as a teacher in Columbia University, until October, when that work had to be resumed, he occupied himself exclusively with the task of putting into final shape for publication the material which he had collected for the Department in the Archives of the Indies at Seville. It will perhaps be remembered that his field in Seville was that section of the Archives of the Indies which is called "Papeles procedentes de la Isla de Cuba," and that his work consisted in examining and taking full notes, with a view to describing all those parts of that section which relate to the history of the United States. This section came originally from the archives of the captain-general at Havana, and was transferred to Spain in 1888. There are 934 *legajos* or bundles relating to the history of the United States, averaging more than 400 documents to the bundle, and having reference chiefly to the period between 1763 and 1819 in the history of those portions of the present United States which were formerly included under the designations Florida and Louisiana in the largest sense of those terms. All these bundles were examined by Mr. Hill during the period of his stay in Seville, and all necessary data noted for a general descriptive inventory. Mr. Hill has now finished the manuscript of this inventory, which it is proposed

to publish in one large volume. In this the contents of each bundle is described, upon a uniform plan, at such length as to constitute about half a page of printed matter. To publish a complete calendar of all these individual documents, approximately 400,000 in number, does not seem to be practicable, but we have such a calendar in manuscript, covering about 143 *legajos* selected as the most important and embracing itemized descriptions of more than 58,000 documents. Mr. Hill's descriptions in the printed book are ingeniously contrived to convey such information respecting each *legajo* as can be given in half a page, and in the case of the 143 *legajos* mentioned it will be possible for investigators who need fuller details to consult these itemized lists in the office of the Department, while investigators at a distance can readily secure photostat copies of such portions of the manuscript calendar as they may desire.

Near the end of the year reported upon, Professor Albert B. Faust, of Cornell University, finished and transmitted to the Department the manuscript of his extensive report upon the materials for American history in the archives of German Switzerland and of Austria, the fruit of his period of investigation in those countries in 1913. These notes, together with those which the Director took in the archives of the French cantons of Switzerland in the summer of 1912, will constitute a printed volume of moderate size. Dr. Faust's manuscript, besides introductions relating to the different aspects in which the Swiss and Austrian materials illustrate the history of the United States, contains full information as to the American contents of the federal archives of Switzerland and of the archives and libraries of the various German cantons, the most extensive being those relative to the cantons of Zürich, Bern, and Basel; also notes from the chief state archives of Vienna, from ministerial and other archives in that city, and from the provincial archives of Salzburg and Innsbruck. They reveal an unexpected wealth of material, illustrative especially of the composition and processes of the German-Swiss emigration to the United States, of Austrian migration before 1848, and of the diplomatic relations between the United States and Austria before that date and between the United States and Switzerland.

It was mentioned in last year's report that an arrangement had been made with Miss Margaret Adam, holder of a fellowship under the Carnegie Trust for the Universities of Scotland, whose special subject of investigation is the migration of Scotsmen to America, whereby she would note for us all references of that sort which commonly make the staple of our Guides. As her investigations will necessarily range through the principal archives of Edinburgh, it is believed that whatever they contain for the purposes of American history will thus be listed in a form which the Department can use, without the necessity of organizing a special mission to Scotland. Miss Adam's first year's

work has lain rather in printed than in manuscript sources, and therefore she has no more than made a beginning of collecting the materials which we desire. In any case, the amount of them in the archives of Edinburgh is not large.

Of the work which Dr. Francis S. Philbrick kindly undertook for the Department in the Archives of the Indies at Seville, one part was seriously interfered with by the outbreak of war, while the other met with considerable success. It was intended that during his summer months in Seville a series of 2,000 photographs, comprising a certain portion of the despatches sent by the Spanish governor of Louisiana to the captain-general at Havana, should be made in the archives by a firm of photographers in Seville. Since the negatives were to be made on paper, and the kind of paper which we had designated had to be imported into Spain from Germany, the outbreak of the war seemed at first to have prevented its procurement. Later advices seem to show that it finally arrived in Seville, and that the photographs will ultimately be made, Dr. Philbrick having designated all the documents systematically before his departure. The printing of copies, for any subscribers who may desire the series, will be subsequently executed in Paris.

On the other hand, Dr. Philbrick was able to carry out, to as large an extent as time permitted, the other part of his undertaking, by searching for materials relating to the United States among the papers in that section of the Archives entitled Audiencia de Santo Domingo, and noting systematically what he found. It is understood that the papers of the Audiencia de Santo Domingo stand next to the Cuban series in value for United States history. Though they are primarily records of judicial and administrative cases, and therefore call for a somewhat different treatment from that which Mr. Hill employed in the case of the Cuban series, the method of notation has been made as nearly as possible the same. The mass of papers in this Audiencia is so large, and the material relating to territories now in the United States is so scattered, that only a beginning, a trial exploration, could be made in one short summer. The results will apparently justify fuller and more continuous exploration at a later time.

In June, Professor William I. Hull, of Swarthmore College, sailed for the Netherlands, to make there an examination of the various Dutch archives and to provide a guide to the materials which they contain for American history. In a month's work he prepared a careful general account of the history, composition, and circumstances of the national, provincial, communal, and ecclesiastical archives of the country, and began a more detailed examination of the archives of the House of Orange, entrance into which was secured for him by the kindness of the American Minister to the Netherlands, Dr. Henry van Dyke. At this point, however, the outbreak of the European war, with the difficulties which this made in the prosecution of his work, and with the

prospect that the Netherlands might be involved, interrupted Dr. Hull's labors and caused him to deem it prudent to return to the United States. It is a pleasure to mention the kindness with which the custodians of the various state archives in the Netherlands have expressed their wish to aid Dr. Hull's researches.

Professor Frank A. Golder, on a year's leave of absence from the Washington State College, agreed to spend three months of that time in the service of the Institution preparing a guide to the materials for American history in the archives of Russia. Arriving in St. Petersburg early in March, he had at last accounts completed his inquiries in that city, and had proceeded to Moscow, where (speaking in general terms) archival materials ante-dating 1801 are to be found. In the archives of the Foreign Office at St. Petersburg he had examined, from 1804 to the latest date permitted by official regulations, the series entitled "Washington," "États-Unis," and "Philadelphie," and the Imperial and Asiatic archives; also the archives of the Ministry of Marine, of the Ministry of Finance, of the Holy Synod, and of the Imperial Council, and the manuscript collections of the Imperial Library and of the St. Petersburg Academy of Sciences. In these various collections he has found copious materials, of considerable importance, for the history of diplomatic relations between the United States and Russia, for the explorations of Bering and others, for the history of the Russian American Company, and for various episodes, such as those connected with John Paul Jones. He has been greatly helped by the kind offices of Mr. Sergius Goriainov, chief archivist of the Foreign Office, of Professor Alexander Lappo-Danilevski, of the Academy of Sciences, who caused the American papers in the archives of Tambov to be brought to that institution for Mr. Golder's use, and of the Archbishop of Warsaw, formerly Bishop of Alaska, through whose means valuable collections of papers relating to the ecclesiastical history of that territory have been thrown open to Mr. Golder's use. He has also inspected an important collection in one of the Russian monasteries, and has supervised the transcribing of historical documents for the Library of Congress.

In the work for the proposed Atlas of the Historical Geography of the United States, Dr. Paullin, with some clerical assistance, has carried practically to its completion the preparation of the sketches for two divisions of the Atlas. The first is that which illustrates the history of presidential elections, by plotting by counties the votes for those presidential candidates who had a plurality of the popular vote in the respective counties. Where popular votes for presidential electors were lacking their place has been supplied by means of analogous data accumulated by patient search of old election returns in the Library of Congress and in State archives. The second series, nearly concluded, is that exhibiting, by congressional districts, votes cast in the House of Representatives for or against each one of a selected series of 32 im-

portant typical measures of national legislation, extending over the period from 1789 to 1914. Voluminous notes have in the meantime been made for the expository letter-press which will accompany these two sets of maps, and which Dr. Paullin is now preparing.

At the beginning of October Professor R. H. Whitbeck, of the University of Wisconsin, on leave of absence from his university, began a series of four months' assistance to the Department in the work of preparation for the Atlas. He has addressed himself chiefly to those maps which illustrate the physical bases of American history and some of the phenomena of the social and economical, especially the industrial, history of the United States.

TEXTUAL PUBLICATIONS OF DOCUMENTS.

The volumes of "Letters of delegates to the Continental Congress" have advanced during the year in three respects. Dr. Burnett has expended much labor upon the careful and scholarly annotation of the letters already collected and copied. The final processes in the preparation of text and notes, in typographical respects, for publication have been well advanced. Thirdly, additional letters have been copied whenever knowledge of them has been obtained, or whenever access has been given to collections not previously available. Although Dr. Burnett's collection had already, many months ago, been made as complete as it could apparently then be made, it is obviously desirable, up to the last practicable moment, to add further materials which may come to light. Often this occurs through the kindness of dealers in autographs. An especially important addition has been made through the favor of Mr. J. Pierpont Morgan in according access to his remarkable autograph collection. Another considerable addition has been made from the papers of James Duane, through the kindness of Mrs. Wilmot Townsend Cox.

Returning to the office of the Department in the last days of the period reported upon, Miss Davenport brings with her the material which will complete the first section of her collection of "Treaties between European powers which have a bearing on American history." This collection, including at the beginning the papal bulls relative to America, extends through the treaties of Westphalia of the year 1648, and will illustrate the whole course of conduct of the European powers with reference to America down to that date. As all but the last of this material has been sent to the Department, in installments from time to time, it has been possible for Miss Sanderlin to bring near to completion the final preparation of text, introduction, bibliographies, and notes for all but the last part of the collection.

In respect to the series of "Proceedings and debates of Parliament respecting North America from 1585 to 1783," the copying, or cutting and mounting, of the entries respecting America in the Journals of the House of Commons and House of Lords in the Parliament of Great

Britain has been completed down to the year 1783. Some progress has been made in copying the American entries in the Journals of the Irish House of Commons, and the preliminary work of selection has been carried through one of the large volumes of the "Acts of the Parliament of Scotland." Meantime, a beginning has been made with the debate material. The card catalogue of materials for this collection, showing each printed version of any speech, or part of a speech, respecting America within the period named, having been completed, except in respect to a small portion of the eighteenth-century material, Mr. Stock, who has now been made editor of the series and under whose supervision all work relating to it has been conducted, has carried somewhat beyond 1700 the process of critical sifting of these materials, and the resulting texts of debates for that period have been copied. Most of the work of search in the Journals of the House of Lords was performed by Dr. Albert C. Dudley, of Baltimore, formerly of the Johns Hopkins University.

MISCELLANEOUS OPERATIONS.

As heretofore, the editing of the "American Historical Review" has been carried on in the office of the Department and by its staff. Aid has been given in a number of ways to the American Historical Association, of which Mr. Leland is secretary. In particular Miss Donnan has edited, for the Historical Manuscripts Commission of that society, the papers of the elder James A. Bayard, representative and senator from Delaware and member of the commission which negotiated the Treaty of Ghent. Mr. Leland's supervision of the calendaring of the papers in the French archives relating to the history of the Mississippi Valley, for a group of American historical organizations, has been accompanied by various similar services rendered by him to the States of Illinois and Mississippi, to the Michigan Historical Commission, and to various individual American investigators who have visited Paris for archive work or have desired information from the manuscripts there. He has also supervised the making in Paris of an extensive series of copies of historical manuscripts for the Library of Congress, an institution to which the work of this Department is constantly indebted, and which responds to all our desires with the utmost liberality.

In Washington also, as in previous years, searches and copies have been made by the Department, or under its supervision, for various historical societies and for many individuals. Letters of inquiry as to historical papers in Washington and other matters have been answered with the usual freedom. It has steadily been regarded as a part of the functions of the Department to further the interests in Washington of all American historical scholars, and to mediate between them and foreign archives and other remote sources of historical information whenever occasion has arisen.

PLANS FOR 1915.

REPORTS, AIDS, AND GUIDES.

The first work of the Department in the year beginning November 1, 1914, should be the final preparation of two books for print. The first of these will be the Guide to the materials for American history in Swiss and Austrian archives, consisting of Mr. Faust's report, supplemented by the materials derived by the Director from the archives of the French cantons of Switzerland. The second will be Mr. Hill's Descriptive Catalogue of the papers concerning United States history in the "Papeles de Cuba" of the Archives of the Indies. Dr. Philbrick's report, representing thus far only a fragment of the total results to be obtained from the Audiencia de Santo Domingo, must wait for its completion by later researches; but the making of prints from the series of photographic negatives obtained by him, in the Cuban or Louisiana section, can be undertaken in Paris after the conclusion of hostilities, or perhaps before.

Mr. Leland, so long as he is detained in Washington, can work over the materials which he has collected, and when the cessation of warfare makes it possible will repair once more to Paris to complete his collection of data. The Department desires, during the year 1915, to carry forward one or the other, as circumstances may make expedient, of two European undertakings, the beginnings of which have been described in a preceding paragraph. The first lies in the Archives of the Indies at Seville. While Dr. Philbrick accomplished all that could be accomplished in a summer's campaign, the results show that, in so brief a period of residence, much time is lost in renewing preliminary arrangements and organizing and training the small clerical staff which is requisite, insomuch that one is forced to the conclusion that expeditions to Seville of so brief a duration are not expedient if longer periods of service can be secured. It is not possible for Dr. Philbrick to contemplate a longer period, in any given year, and it may not be possible for Mr. Hill. However, if he, or any agent possessing competence at all approaching his, can be engaged to go to Seville in September 1915, with a view to continuance during nine months or a year, the Department would wish that the completion of Dr. Philbrick's calendar of papers relating to United States history in the Audiencia de Santo Domingo should be then undertaken. It is also desirable to bring to completion Professor Hull's examination of the Dutch archives, unfortunately interrupted last summer by the approach of war.

It is hoped that, with more assistance available for the task than hitherto, including during the first month of the year the valuable services of Professor Whitbeck, our labors on the Atlas of the Historical Geography of the United States may during the year be advanced under Dr. Paullin's direction through or into several other sections of the proposed work.

TEXTS.

Dr. Burnett will expend as large a part of his time as is possible upon his "Letters of delegates to the Continental Congress"; Miss Davenport will give all of her time to the book of treaties, hoping to complete it to 1713, the year of the treaties of Utrecht, before the end of the year. The work upon the "Proceedings and debates in Parliament respecting North America" will consist in constituting, to as late a period in colonial history as time permits, the texts of the Parliamentary debates respecting America. It is also planned that most if not all of the appropriate material in Cavendish's reports of debates, and other manuscript materials in the British Museum, shall before the end of the year be copied for the purposes of our compilation.

MISCELLANEOUS OPERATIONS.

The Department will no doubt maintain, in 1915, activities similar to those described above, under this heading, in that portion of this report which relates to the last twelve months. It is confidently believed that the presence of Admiral Mahan as a Research Associate will stimulate all the work of the Department. It will certainly cause all those who are occupied in its activities to appreciate more vividly the relation of those activities to the work of historians and to the general progress of historical study and literature.

DEPARTMENT OF MARINE BIOLOGY.*

ALFRED G. MAYER, DIRECTOR.

The past year has been both varied in events and successful in achievement and marks also the completion of the first decade in the existence of the Laboratory. It may seem opportune, therefore, after having spoken of the events of the present, to review briefly those results which have gained acceptance among men of science, for the success or failure of the Laboratory must be estimated not in terms of our hopes, but in those of convincing achievement as demonstrated in publications. Responsible as we are for that wisdom in expenditure which should result in the construction of well-equipped laboratories and the providing of the best of opportunities for research, yet in a far greater degree must we be accountable for the results achieved, which must be at least commensurate with the material advantages which have been so generously granted to us.

THE EXPEDITION TO TORRES STRAITS, AUSTRALIA.

The success of the expedition to Torres Straits, Australia, was in the greatest measure due to the generous response upon the part of the officers of the Australian governments to the highly appreciated letters of introduction from Lord Bryce, then British ambassador to the United States. It is a pleasure to refer especially to the kindly and efficient interest in our behalf displayed by Sir William Macgregor, M. D., G. C. M. G., C. B., governor of Queensland; by the Honorable P. J. McDermott, I. S. O., chief under secretary, by the Honorable W. M. Lee-Bryce, the resident at Thursday Island, and by Judge A. W. Macnaughton, of the Supreme Court of Queensland.

In Papua, also, the officers of government were most cordial in their interest and we were honored by an invitation to remain as guests of the governor, His Excellency the Honorable John H. P. Murray, M. A., during the entire period of our stay in New Guinea.

Our expressions of gratitude are also due to R. Etheridge, esq., curator of the Australian Museum in Sydney, who not only gave us advice and aid of fundamental importance, but was most solicitous for the welfare of Dr. Harvey during his illness in Sydney, upon his return from Murray Island. To the distinguished student of coral reefs, Charles Hedley, esq., we are indebted for the advice that led to our going to Murray Island. Messrs. J. B. Arthur and R. A. C. Hockings, of Thursday Island, kindly permitted members of the expedition to sail from Thursday Island to Darnley Island on their power schooner

*Situated at Tortugas, Florida. (For previous reports see Year Books Nos. 3–12.)

Kestrel, thus forwarding greatly the success of the expedition. We also enjoyed the privilege of being the guests of Mr. Thomas Arnold Williams, of Darnley Island, and of John Stewart Bruce, J. P., the well-known anthropologist and teacher of Murray Island, whose advice and generously offered aid was invaluable to us upon many occasions, placing at our service all the fruits of his more than twenty years' experience upon these remote and interesting islands. To the Rev. F. W. Walker, managing director of the Papuan Industries, a philanthropic association devoted to teaching the natives useful arts and trades, members of the expedition are indebted for a profitable and happy week upon Badu Island.

Early in September the Director, accompanied by Messrs. Hubert Lyman Clark, E. Newton Harvey, Frank A. Potts, David H. Tennent, E. M. Grosse, of Sydney, the artist to the expedition, and our engineer, Mr. John Mills, arrived at Thursday Island, at the northern extremity of Cape York, Queensland. We had hoped to establish a laboratory at Thursday Island, but it soon became apparent that the strong currents had covered the reef-flats with silt, killing most of the corals and echinoderms.

Fortunately, Mr. Charles Hedley, of Sydney, had told us of the clear, blue water and rich coral reefs of the Murray Islands, within 6 miles of the outer line of the Great Barrier Reef and 120 miles ENE. of Thursday Island. Generously aided and advised by the Honorable W. M. Lee-Bryce and by Messrs. Arthur and Hockings, the expedition reached Darnley Island in the schooners *Kestrel* and *Venture*, where we were hospitably entertained by Mr. T. Arnold Williams. Finally, on September 20, we reached Maër Island, of the Murray Islands, and were permitted to make use of the concrete courthouse and the palm-thatched "jail" for laboratory purposes, Messrs. W. M. Lee-Bryce and John Stewart Bruce putting at our disposal these quarters, which made an ideal tropical laboratory.

At Murray Island the expedition achieved a signal success. The region is one of rich coral reefs, bearing a varied molluscan and echinoderm fauna well suited to provide material for the experimental studies we purposed to conduct. The reef-flat on the southeastern side of Maër Island is about 2,000 feet wide and is covered by water about 18 inches deep at low tide, forming a wide, shallow marine lake, dammed on the seaward edge by the lithothamnion ridge of the reef. The fauna of this tidal lake is one of the richest in the tropical world, and Dr. Hubert Lyman Clark was enabled to collect 151 species of echinoderms in shallow water along the shores of Maër Island; he also found 26 others at Badu and at Thursday Island; and at least 45 of these are new to science. Thus, as a result of the studies of Dr. Clark and of those who preceded him, 250 species are now known from the Torres Straits region. His collection is a notable addition to that of the Museum of

Comparative Zoology at Harvard, already probably the richest gathering of specimens of echinoderms in the world. Dr. Clark's report may be awaited with enhanced interest, due to the 100 or more admirably colored drawings of Murray Island echinoderms made from life by Mr. E. M. Grosse and now being lithographed by him in Sydney. Dr. Clark also spent much time in observing the movements and reactions to light of the crinoids, but details of these and other matters pertaining to his work will appear in his preliminary report presented on a following page.

While at the Murray Islands, Dr. E. Newton Harvey, of Princeton University, discovered a large holothurian, *Stycopus ananas*, or "prickly fish" of the beche de mer industry. The intestines and gonads of this animal are provided with a red pigment which changes to carroty-red in acids and to purple in alkalis, these changes being reversible. The presence of this natural indicator gave Dr. Harvey a unique opportunity to study the rate of penetration of 26 different acids, and he found that living cells resist the entrance of all acids with the exception of salicylic, benzoic, and possibly valeric, but this resistance is slight compared with that for alkalis. There is no relation between rate of penetration and degree of dissociation, nor between degree of dissociation and toxicity, but there is a fair coordination between penetrability and toxicity, the most toxic being the ones which penetrate most rapidly. Also, with acids as with alkalis, if the acid is soluble in fatty substances, it usually penetrates rapidly, but if insoluble or only slightly soluble in lipoids, it can enter the cell only slowly, if at all. Details appear in Dr. Harvey's preliminary account published herewith, and his full report is now in press and is to appear in Traube's "Internationale Zeitschrift für Physikalische-Chemische Biologie."

Mr. Frank A. Potts, Fellow of Trinity Hall, Cambridge, and Balfour Student of the University of Cambridge, carried out an interesting series of observations, discovering the male of the so-called gall-forming crab *Hapalocarcinus*, the female alone of which forms capsules among the branches of the coral *Pocillopora*, causing the branches to enlarge by the effect of the water-currents from its gills until it becomes imprisoned in a chamber formed by the coral. The minute, free-swimming male probably enters the capsule only when the female molts.

The life-history of a curious parasitic cirriped, *Thylacoplethus*, which infests the snapping shrimps, *Alpheus*, that live among the arms of crinoids, also engaged the attention of Mr. Potts; and he observed that the male of the hermit crab *Pagurus deformis* has inherited a single sexual character belonging to the female, having, in addition to its male genital apertures, a pair which are without ducts but are homologous in position with those of the female.

The Director made an intensive œcological and physiological study of the coral reefs at Maër Island, finding that temperature is the chief factor which determines the habitats of the various species upon the reef-flat. Moreover, in general it appears that in proportion as a coral is able to withstand high temperature, it can usually in like ratio survive being buried under the mud. This suggests that high temperature may produce death in corals by causing asphyxiation in the manner stated by Winterstein in the case of frogs. Some corals, however, such as *Favia fragum* and *Mœandra areolata*, die at relatively low temperatures, but are highly resistant to the smothering effects of CO_2 or of being buried under the sand; yet they are nearly as resistant to heat when buried as they are when living in the free open water, while those corals that die at moderate temperatures are much more sensitive to temperature when buried than when not buried. It seems, therefore, that certain corals can, so to speak, go into a state resembling hibernation and still survive at a much lower metabolism than the normal, whereas other corals, such as *Acropora* and *Orbicella*, can not adjust themselves in this manner, but die if their metabolism be appreciably lowered. Possibly similar relations may pertain to other hibernating animals and may in a measure account for the observations of Amerling and of Babàk, that certain frogs and toads which died at a moderate temperature could survive well in deficiency of oxygen, while others which died at a high temperature were easily asphyxiated. In other words, the vital limits of some animals may be adjustable, some to higher and some to lower rates of metabolism than the normal, whereas others may be confined to a relatively narrow temperature range.

But to return to the corals: It was found that the physiological reactions of the Pacific corals are similar to those of related Atlantic genera, and that natural selection has not enabled the Florida corals to increase their resistance to the cold of winter, or the Torres Straits forms to better withstand the deadly heat of their hot season. There is clear evidence of a struggle for existence among the various species of the Murray Island reef-flat, but none whatsoever that any of these species has thereby been improved by a selective process.

It was found that the range in temperature of the water over shallow reef-flats is considerably greater than that of the air above them, thus showing that solar radiation, not conduction from the air, is the chief source of heat for the ocean water.

There is clear evidence of solution of limestone over the reef-flats everywhere in Torres Strait, but we are not yet prepared to assert that the sea-water *as such* causes this solution, for there are many other factors, such as rain-water draining from the land, decomposition of organic matter, acid-producing algæ, worms, sponges, and mollusks, and the digestive effects produced by echinoderms upon sand in their alimentary tracts. One should consult Dr. Tashiro's report, published

herewith, for further discussion of this problem, which is now being studied in various aspects by Doctors Vaughan and Tashiro, and by the Director at Tortugas.

The Pacific reefs are distinguished from those of the Atlantic by their lithothamnion ridge, forming a breakwater along the crest of the sea face of the reef often nearly a foot above low-tide level. Also, there are about twice as many species of reef corals in the Pacific as in the Atlantic, and some of these grow in abundance at depths below those in which the Atlantic forms are common. Gorgonians are by no means so common over the Pacific as over the Atlantic reefs, but the fleshy alcyonaria, such as *Sarcophyton*, often carpet wide areas over the reef-flats of the Pacific. It may be of interest here to observe that Dr. L. R. Cary, as a result of his studies at Tortugas this summer, is enabled to state that the calcareous spicules of gorgonians contribute more limestone to the reefs than do the skeletons of the madreporian corals.

It is deeply to be regretted that illness prevented Dr. T. Wayland Vaughan from accompanying the expedition and continuing in the Pacific the excellent work he has performed upon the reefs of the West Indian region, and it was because of the absence of Dr. Vaughan that the Director felt compelled to attempt the study of the corals of Torres Straits.

Professor David H. Tennent, of Bryn Mawr College, succeeded in effecting a hybrid cross between a male crinoid *Comatula purpurea* and a female *Echinaster*, and he raised the larvæ to a more advanced stage than had hitherto been done; but the reciprocal cross could not be made, for it being the spring of the year (September and October), the eggs of the crinoids were not yet ripe. Later, at Badu Island, Professor Tennent made a detailed study of *Laganum* and *Salamacis*, the larval development of which had hitherto been unknown, and he also observed the early parthenogenetic development of these forms. It is hoped that he may return to Torres Straits in the height of the echinoderm breeding-season, for he is now prepared to conduct an important research upon these forms. As in Professor Tennent's case, so has it usually been at Tortugas. During the first season an investigator commonly succeeds only in discovering the material or in developing the method for some important study, and only upon his succeeding visit is a well-rounded research produced.

By making use of mosquito bars and by taking other precautions, we were enabled to avoid the malarial fever of the Murray Islands and of New Guinea. Two members of the expedition were, however, affected with the "New Guinea ulcers," so much dreaded by unacclimated people in these regions, but fortunately these troubles did not arise until after the scientific work of the expedition had been accomplished, and in neither case was any permanent impairment of health sustained.

CRUISE ALONG THE FLORIDA KEYS.

Upon returning to America, the *Anton Dohrn* was placed in commission and employed from April 20 upon a 10-day cruise to the Tortugas and back to Miami, the object being to enable Dr. Paul Bartsch to study the many colonies of cerions from Andros Island, Bahamas, which he had planted upon the Florida Keys in May and June 1912. These colonies range over a line 225 miles in length from the Ragged Keys near Miami to the Tortugas, and had suffered various fates, some having prospered and produced many young, while others, placed in adverse environments, had died without leaving progeny; but in all cases where young had been produced in Florida, they differed either in form or color from their Bahama-born parents, and displayed a wider range of variability. Moreover, the same species of parents produced different sorts of young in different localities, and thus the mutation appears to be due to some effect of the environment reacting either upon the germ-cells of the parent or upon the growing young as individuals. For details one should consult Dr. Bartsch's preliminary report (pages 195, 196). His very important study has indeed only begun, yet enough has been accomplished to lead one to believe that a flood of light will soon be thrown upon the obscure subject of molluscan variation, and that we may be enabled to ascertain the underlying causes which have resulted in the extraordinarily rich variety of mutations in the Achatinellidæ of Hawaii or the Partulæ of Tahiti.

CRUISE TO THE BAHAMAS.

After returning to Miami, the *Anton Dohrn* again set forth, on May 1, 1914, this time for the Bahamas, with Dr. Thomas Wayland Vaughan.

In this connection the Director desires to express his gratitude to His Excellency the British Ambassador, Sir Arthur Cecil Spring-Rice, who, upon the instigation of President Woodward, kindly gave to us letters of introduction to the governors of the Bahamas and of Jamaica. To His Excellency Sir George B. Haddon-Smith, C. M. G., governor of the Bahamas, and to the Honorable W. Hart-Bennett, C. M. G., the colonial secretary, we are indebted for acts of kindness which contributed materially to the success of the expedition, as did also the courteous and efficient advice and aid rendered by our American consul at Nassau, the Honorable W. F. Doty.

Messrs. Lenox E. Forsyth and E. W. Forsyth renewed their kind acts of former years and guided Dr. Vaughan to places of geologic interest upon Andros Island.

Dr. Vaughan found that the corals which he had measured and cemented upon tiles at Golding Cay, Great South Bight, Andros Island, in 1912, had survived well and had grown at about the same or a some-

what slower rate than do the corals at Tortugas, Florida; but his energies were mainly devoted to a study of the geologic history of the Bahamas, and he traced clearly the several emergences and submergences of the group since Pleistocene times. His special report should be referred to for details, but it may be stated here that the Bahamas were once at least 40 to 60 feet higher than they are at present and the present archipelago of the Great Bahamas consisted largely of a great island extending from the borders of the Gulf Stream to Eleuthera, Exuma, Long Island, and Cay Verde on the east, and New Providence, the Berry Islands, and Great Isaac on the north; thus the Great Bahama Bank, together with Andros, was raised above the sea, forming a huge U-shaped island with the deep tongue of the ocean in its midst.

Dr. Vaughan found the shore platforms, now submerged, which marked the former sea-levels; he also gathered novel physiographic data of importance, enabling him to ascertain the history of wave and wind actions upon denuded shore-lines.

It is now clearly demonstrated that the æolian formations of the Bahamas are superimposed upon a limestone which was formed beneath the sea, but is at present slightly elevated above the level of the ocean. Dr. Vaughan thus supports and amplifies the view put forth by Shattuck, which is opposed to that of Alexander Agassiz.

A collection of corals was made on the barrier reef of Andros Island at Bethel Entrance, and a map of this dangerous reef region was made from a plane-table survey by the Director.

Upon returning to Florida in June, Dr. Vaughan made observations with Ekman meters upon the currents of the Hawk Channel, Rebecca Channel, and Tortugas; and as a result of dredging, both in the Bahamas and in Florida, he obtained data upon the extension of reef-corals to depths down to 20 fathoms.

Dr. Vaughan also continued his study of oölite formations and collected samples of mud and of sea-water, the bacterial content of which are being studied by Dr. Karl F. Kellerman, who finds that the "*Bacterium calcis*" of Drew produces no precipitation of calcium carbonate in sea-water unless in the presence of carbon dioxide. Indeed, for the precipitation of calcium carbonate in sea-water, it appears necessary to have an ammonium-producing organism act in association with one which produces carbon dioxide.

Throughout the period of Dr. Vaughan's association with the Department of Marine Biology, he has been most generously aided in his studies upon numerous occasions by the U. S. Geological Survey, the Smithsonian Institution, the U. S. Bureau of Fisheries, the Department of Agriculture, the U. S. Coast and Geodetic Survey, and the Lighthouse Board, and it is with keen pleasure that as Director of the Department I express warm appreciation of the kind acts of the officers

of these scientific institutions, who through lending apparatus, making analyses, and providing data have effectually aided Dr. Vaughan in conducting the most extensive and at the same time most intensive study as yet achieved by any investigator upon a region of tropical marine limestones.

The following table gives the names of the sixteen investigators who studied under the auspices of the Department during the year from October 1913 to October 1914:

Investigator.	Object of investigation, etc.	Time and place of investigation.
Stanley C. Ball, Yale University	Artist: Insects of Tortugas	June 17 to July 30, at Tortugas.
Paul Bartsch, U. S. National Museum, Washington, D. C.	Mutation of Bahama cerions taken to Florida.	Apr. 20 to 30, at Florida Keys and Tortugas.
L. R. Cary, Princeton University	Regeneration, alcyonaria, etc.; gorgonians as reef-builders.	June 17 to July 30, at Tortugas.
Hubert Lyman Clark, Harvard University.	Echinoderms	Tropical Pacific, August to December 1913.
Ulric Dahlgren, Princeton University	Electric organs in fishes	Beaufort, N. C., and Hampton Roads, Va., July 1914.
E. W. Gudger, State Normal College, North Carolina.	Anatomy of fishes	June 29 to July 30, at Tortugas.
F. P. Gulliver, Washington, D. C.	Cuspate forelands in Florida.	Apr. 25 to May 1, at Tortugas.
E. Newton Harvey, Princeton University.	Penetrability of living cells by acids.	Sept. and Oct. 1913, Murray Islands.
H. E. Jordan, University of Virginia	Anatomy of turtles	June 17 to July 10, at Tortugas.
W. H. Longley, Goucher College	Color patterns of reef fishes, and œcology of reef animals.	June 17 to July 30, at Tortugas.
Frank A. Potts, Trinity Hall, Cambridge.	Habits and anatomy of Crustacea.	Sept. and Oct. 1913, Murray Islands.
Edwin E. Reinke, Rice Institute, Texas.	Dimorphic spermatozoa of Mollusca.	June 17 to July 30, at Tortugas.
Shiro Tashiro, Chicago University	Metabolism of animals, etc., as determined by CO_2 production.	June 17 to July 30, at Tortugas.
D. H. Tennent, Bryn Mawr College	Hybrid echinoderms	Sept. and Oct. 1913, at Murray Islands.
A. L. Treadwell, Vassar College	Eunicidæ and other annelids of Tortugas.	June to July 30, at Tortugas.
T. Wayland Vaughan, U. S. Geological Survey.	Geology and coral reefs of the Florida-Bahama region.	May 1 to June 29, at Bahamas and Tortugas.

STUDIES AT TORTUGAS IN 1914.

The season at Tortugas, Florida, lasted from June 9 to July 30, when the Laboratory was closed for the season in order to permit Dr. Harvey and the Director to go to Jamaica, in order to present a letter of introduction to the Governor from the British Ambassador, Sir Arthur Cecil Spring-Rice, and also to conduct several researches and to determine with greater definiteness the best site for the research laboratory which it is hoped may be established in Jamaica; but these plans were temporarily frustrated by the sudden advent of the European war.

At Tortugas we enjoy to the fullest degree the rare advantage of that isolation so felicitous to the prosecution of research, and our Laboratory having been improved each year remains the best equipped marine station in the tropical world. Moreover, the fauna is now well known to us and certain of the animals, such as *Cassiopea*, have provided exceptionally favorable material for researches in physiology. But the abandonment of Fort Jefferson as a naval base has caused the withdrawal of all communication with Key West, distant 68 miles from Tortugas, and in order to maintain ourselves at Tortugas we are obliged to make frequent voyages in the *Anton Dohrn* to Key West and return, thus greatly increasing the cost of maintenance and interfering with the orderly progress of the research work of the laboratory.

It seems necessary, therefore, to use the Tortugas in future as a branch laboratory and to establish our main station upon some such island as Jamaica, the accessibility and healthfulness of which is being rapidly improved, due to the new prosperity which has come as a consequence of the opening of the Panama Canal. This would permit the use of the *Anton Dohrn* for purely scientific work instead of as a passenger and freight carrier, and the many problems of the oceanography of the Florida Straits, the Tongue of the Ocean, the Bahamas, Cuba, and the Gulf of Mexico would at once fall within the scope of our resources.

Our buildings at Tortugas, while excellent for essential purposes, are cheaply constructed of wood and were designed from the first to be temporary structures; and in fact the total cost of all laboratory structures and docks at Tortugas to date, including the $4,000 insurance loss due to the hurricane of October 1910, has been $13,719, while the total cost of the operations of the Laboratory has been $213,860. Thus, less than one-fifteenth of the expenditure has been for buildings, and the chief value of our property is in vessels, machinery, equipment, and apparatus. Moreover, it is not proposed to abandon the Tortugas plant, but to use it only for certain researches for which it affords preeminent advantages.

The cheap cost of labor in Jamaica and the training the negroes have received in erecting reinforced-concrete structures in the rebuilding of Kingston will render it a relatively inexpensive matter to conduct there a laboratory which will be both scientifically serviceable and

architecturally attractive, and the Director's visits to Oxford and Cambridge have assured him of the cordial support of the best trained English investigators as well as those of our own country.

Such a laboratory in Jamaica could be maintained for less cost than one in our own country and could be open throughout the year for the reception of investigators. Indeed, the rapid improvement of Jamaica as a health resort and as a center of awakened commercial and social activity renders it possible to establish there a marine laboratory that may attain in the western world to the position held by the Naples Station in the advancement of science in Europe.

With the exception of Dr. Tashiro, all the investigators at Tortugas came to continue or to complete researches commenced in past years, the idea being, in so far as possible, to complete the studies at Tortugas before assuming new researches at Jamaica.

Dr. Stanley C. Ball served as draftsman in making colored drawings of the Eunicidæ for Professor Treadwell's research upon these worms, which has now been pursued for four seasons, 210 figures having been completed. The artistic excellence of this work, in connection with the thoroughness of Professor Treadwell's observations, should result in the production of a publication comparable with the beautifully illustrated systematic monographs of the Naples Laboratory.

Of Dr. Paul Bartsch's interesting work we have already spoken, and also of that of Dr. T. Wayland Vaughan.

Dr. Louis R. Cary carried out an extensive study upon regeneration in *Cassiopea*, finding that if the marginal sense-organs be present the early stages of regeneration are much more rapid than if they be removed. He also showed that this is not due to the movements of the medusa, for when the sense-organs are removed and a circuit wave maintained in the subumbrella tissue, regeneration occurs at the same rate as when the sense-organs are removed, and, on the other hand, if the sense-organ be prevented from initiating pulsation by the action of magnesium, regeneration is still more rapid than if they be removed.

In another research, Dr. Cary separated the calcareous spicules from the fleshy and horny substance of gorgonians and found that 20 to 35 per cent of the weight of these forms is due to the spicules, and thus the gorgonians actually contribute more calcium carbonate to the reef limestones than do the madreporian corals.

Professor Eugene W. Gudger continued his study of the anatomy of sharks and rays, finding one species new to the Florida region. He also dissected many teleosts, discovering much that has hitherto been undescribed in their anatomy, and, in connection with Professor Longley, he identified many species of reef fishes of the Tortugas.

Professor W. H. Longley continued his study of the œcology of the reef fishes, with a view to throwing light upon the causes that have influenced the color patterns of these often brilliantly colored animals. He found that certain of the conspicuously colored yellow, blue, and

green species which swim among the coral heads by day bury themselves under the sand at night; while, on the other hand, the red-colored fishes with large eyes, such as *Amia* or the squirrel-fishes, remain hidden in crevices by day and wander out only at night. In this connection it is interesting to observe that Helland-Hansen discovered that the red rays are absorbed in the upper layers of the ocean, leaving only the blue and violet rays to penetrate to the greater depths. Thus the red does not penetrate to the deep-sea floor, and the prevailing red color of the animals there is apparently protective; for, as there are no red rays around them, they appear black. Professor Longley's observation that red fishes of the shallow waters are nocturnal appears to be an interesting extension of this principle.

Professor H. E. Jordan obtained and successfully preserved a complete set of embryos of the loggerhead turtle, *Caretta caretta*, for anatomical study. One of these turtles laid its eggs on May 28, and the young hatched on July 25 and 26.

Dr. Edwin E. Reinke continued his observations upon the reactions of the two kinds of sperm of prosobranch mollusks, finding additional evidence for the view that the apyrene sperm serves as nurse-cells to maintain the active eupyrene sperm. These sperm-cells appear to be sensitive to changes in CO_2 and to the effects of surface tension in the manner explained in Dr. Reinke's report published herewith.

As is well known to biologists, Dr. Shiro Tashiro has for several years been studying the rate of metabolism as measured by CO_2 production in *Limulus* at Woods Hole, Massachusetts. He came to Tortugas to continue these studies upon the *Limulus* of Marquesas, Florida, making use of the "biometer," an apparatus of extreme delicacy, which he himself invented and which enables one to detect minute amounts of CO_2 by means of a drop of barium hydrate, upon the surface of which crystals of barium carbonate form if there be carbon dioxide in the surrounding atmosphere. He found that the metabolism of the Florida *Limulus* is lower than that of those living at Woods Hole, and that a rise or fall in temperature affects the warm-water forms to a greater degree than those of Woods Hole. This is in accord with the observations of Dr. Harvey and of the Director upon the temperature reactions of other tropical marine animals.

Dr. Tashiro also made a study of the metabolism of *Cassiopea*, both in natural and in diluted sea-water, and also in sea-water mixed with magnesium chloride. He also found that among corals the *Acropora muricata*, which can not withstand high temperature and is easily asphyxiated, has a high rate of metabolism, whereas *Siderastrea radians*, which is very resistant both to high temperature and to asphyxiation, has a low rate of metabolism.

He also made the very interesting observation that carbon dioxide is given off into the atmosphere from the sea-water of Tortugas under

normal atmospheric pressure and temperature. This leads one to suspect, but not to conclude, that uncombined carbon dioxide may be present in the surface-water of the sea and that the Tortugas water may thus be capable of dissolving limestone. This matter should, however, be tested by further experiments before we may venture upon any definite statement, and such tests are now being conducted by Drs. Vaughan, Dole, and Tashiro and by the Director.

Professor Ulric Dahlgren spent nearly six weeks at Beaufort, North Carolina, and succeeded in obtaining the young of the "star gazer," *Astroscopus*, in order to study the development and histology of its electric organs, which are formed from modified eye muscles. He has shown that the development of electric tissue in seven types of fishes is independent one of the other and is comparatively recent. For details one should consult not only his report upon the habits of *Astroscopus* published herewith, but his interesting paper upon "The electric tissues of *Gymnarchus*," in Publication No. 183 of the Carnegie Institution of Washington. It is hoped that his interesting studies may be continued in South America and in Egypt.

Dr. A. G. Mayer made an extensive series of kymograph records of the rate of nerve conduction in *Cassiopea* at Tortugas. Experiments were carried out upon 211 medusæ in diluted and in evaporated (concentrated) sea-water; also in sea-waters wherein the osmotic pressure was higher than the normal, while the concentration of the electrolytes was that of natural sea-water. It is well known, from the work of Loeb and of Goldfarb, that concentrated sea-water inhibits growth and regeneration to a greater degree than does a corresponding dilution, but the cause of this difference is not known and it is hoped that these kymographic records may throw light upon this matter and enable us to determine the formula expressing the relation between rate of nerve conduction and degree of concentration of the ions surrounding the nerves. Several months must elapse, however, before the thousand or more observations can be tabulated and reduced to mathematical expression.

Volumes 5 and 6 of Papers from the Tortugas Laboratory (Nos. 182 and 183 of publications of the Carnegie Institution of Washington), containing 23 articles, appeared during the year, and the following six papers were also published as a result of studies carried out under the auspices of the Department of Marine Biology:

Changes in concentration of sea-water and their influence upon regeneration. A. J. Goldfarb, Proc. Society Experimental Biology and Medicine, vol. 10, No. 3, 1913.
The influence of the central nervous system in regeneration of an annelid worm. *Ibid.*
Cell permeability for acids. E. Newton Harvey, Science, vol. 39, p. 947, 1914.
An expedition to the coral reefs of Torres Straits. A. G. Mayer, Popular Science Monthly, vol. 85, pp. 209–231, September 1914.
Sketch of the geologic history of the Florida reef tract and comparisons with other coral-reef areas. Thomas Wayland Vaughan, Journal Washington Academy Sciences, vol. 4, pp. 26–34.
The platforms of barrier coral reefs. Thomas Wayland Vaughan, Bulletin American Geographical Society, vol. 46, pp. 426–429.

A SUMMARY OF THE RESULTS ACHIEVED BY THE LABORATORY DURING THE TEN YEARS, 1905-1914.

During these first ten years of its existence, 49 investigators have studied under the auspices of the laboratory; 28 of these have returned two or more times to the station, and thus a total of 108 visits have been made to the laboratory for the purpose of investigation.

The Carnegie Institution of Washington has published 49 papers as a result of the researches of these students, and also 11 others resulting from the work of the Director, or 60 in all; this enumeration does not include papers now in press or preliminary reports in the Year Books of the Institution. In addition, at least 44 papers have been published by agencies other than the Institution. Thus at least 104 papers have resulted from the researches of the laboratory, the Carnegie Institution of Washington itself having published 2,251 pages and 269 plates, exclusive of preliminary reports in Year Books.

In Year Book No. 8, 1909, pages 146–153, may be found reviews of all researches which were completed during the first five years of the work of the laboratory, and we will not again refer to these, but will mention only those which have resulted from the studies of 1909 to 1914.

During this period, studies in systematic zoology have been published by Hartmeyer on Ascidians, Jörgensen on Peridinea, Linton on Trematodes and Cestodes, Mayer on Ctenophoræ and Medusæ, Osburn on Bryozoa, and Treadwell on Annelids. Some of these papers have been of considerable length, one consisting of 735 pages, but it will be impracticable to review them in this brief summary.

The interesting studies of Dr. Paul Bartsch upon the mutations of cerions transplanted from the Bahamas to Florida have been mentioned elsewhere in this report, and attention should also be called to his notes upon migrating birds published in the Year Books for 1913 and 1914.

Dr. Louis R. Cary has carried out an important series of observations upon the growth-rate and œcology of gorgonians. He finds that in order to secure an anchorage, the planulæ must usually settle in crevices or in protected places, and the young gorgonian (*Plexaura flexuosa*) usually reaches 30 to 45 millimeters in height by the end of the first year, the breeding-season being at its height in June. Severe storms are probably the most destructive factor in the œcology of gorgonians, for the colony is often torn bodily from the reefs with its rock of attachment, and if thrown over upon its side, death soon results. Dr. Cary found that the bulk of calcareous matter composing the spicular skeletons of gorgonians ranges from 20 to 35 per cent of the entire weight of the animal, and thus upon dying they contribute a greater amount of carbonate of lime to the reef flats of Florida than do the stony corals. Gorgonians have a fair degree of regenerative ability, abraded places

being soon covered with scar tissue which in time develops polypites over its surface.

Dr. Hubert Lyman Clark made a detailed study of the growth-changes in brittle-stars, *Ophiothrix*, *Ophiactis*, and *Amphipholis*. His conclusions being based on the observation that as the terminal segments of the arms of these star-fishes are the youngest, they may be expected to reveal the developmental stages through which the arm has passed. He calls attention to the fact that the genetic relationships of ophiurans can be determined only when we know the history of the changes in appearance and structure of their skeletal plates and organs during growth from the young to the adult stage.

Mr. R. B. Dole analyzed a series of samples of the lagoon water of the Tortugas atoll which had been collected throughout a lunar month, at all stages of the tide, by Dr. T. Wayland Vaughan. Mr. Dole concluded that there is no free carbon dioxide either in the Tortugas lagoon or in the surface-waters of the ocean surrounding the islands, and that the sea-water has no power to dissolve limestone by virtue of its content of carbon dioxide. Should this conclusion be confirmed, it is one of primary importance from a geologic standpoint, for it would indicate that solution has had no part in the formation of the lagoons of coral atolls and barrier reefs.

An important research was conducted by the late George Harold Drew, of Cambridge University, England. Dall was the first to assert, and Sanford and afterward Vaughan concluded, that the finely divided limestone mud of the lagoons and sounds of southern Florida was a chemical precipitate. The cause of the precipitation remained a mystery, however, until Drew discovered that there is in the surface waters of the Florida-West Indian region a very abundant bacillus which, if grown in sea-water containing calcium malate or calcium succinate in the presence of a nitrate, changes the nitrate into nitrite and finally causes nitrogen to be set free and to escape from the solution. Drew concluded that this reaction must cause a precipitation of calcium carbonate in the sea-water. After Drew's death, Dr. Karl F. Kellerman studied this process and found that Drew's bacillus did not produce a precipitate of calcium carbonate in pure sea-water unless free carbon dioxide was present, and he concluded as a result of further experiments that calcium carbonate is precipitated from ocean-water if an ammonium-producing or a denitrifying organism is grown in association with one which produces carbon dioxide.

As a result of these studies, we now know that limestone is constantly being precipitated to form the impalpable mud of the Bahama banks and Florida lagoons, and, moreover, the conclusions of Brandt are confirmed, that the relative paucity of plant life in tropical oceans (and consequently the scarcity of animal life), is due to the relative lack of nitrogen in warm seas.

Finally, Vaughan has been able to demonstrate experimentally that this limestone precipitate undergoes chemical and physical changes which result in the aggregation of its particles to form the oölite granules in the manner described by Linck.

Dr. A. J. Goldfarb developed a new method for causing echinoderm larvæ to fuse together, by placing the fertilized eggs in a solution of one part of sea-water to three parts of isotonic or slightly hypotonic sodium chloride. When both of two fused embryos developed equally fast, each was perfect, but when one fused larva developed more slowly than the other, it atrophied and finally disappeared without producing any effect upon the dominant larva except upon its skeleton.

In another research Dr. Goldfarb demonstrated that, in common with the earthworm, the marine annelid *Amphinoma* can regenerate lost parts without contact of or stimulation from the nerve-cord or central nervous system.

In another series of experiments Dr. Goldfarb showed that the scyphomedusa *Cassiopea* regenerates more rapidly in dilute than in normal sea-water, and also that a slight degree of concentration is much more injurious than a corresponding dilution of normal sea-water. These results are quite similar to those previously obtained by Goldfarb in his study of the hydroid *Eudendrium*, and confirm the earlier work of Loeb, that regeneration in *Tubularia* is more rapid in dilute than in natural sea-water and that concentration above the normal causes a rapid falling off in rate of regeneration.

In this connection it may be of interest to state that Mayer found that the rate of nerve conduction in *Cassiopea* is more rapid in slightly diluted than in natural sea-water.

Professor Eugene W. Gudger has discovered much that is new and interesting in the anatomy of sharks, rays, and bony fishes, and his published study of the eagle ray is a model of scholarly research in the field of systematic zoology.

Dr. E. Newton Harvey found that the rate of nerve conduction in *Cassiopea* increases in a right-line ratio as the animal is heated from about 15° up to about 36° C., above which there is a sudden falling off in rate. The curve, superficially at least, resembles that of enzyme actions. Later, Mayer repeated these experiments and confirms Harvey's curve, which may, however, represent either an enzyme reaction or, possibly, the resultant between two antagonistic tendencies—an acceleration in accord with the van't Hoff chemical reaction curve offset by a retardation due to the development of asphyxiation produced by high temperature.

In another research Dr. Harvey found that in acids there is no relation between dissociation and their rate of penetration of living cells, but the more poisonous acids penetrate more rapidly than those which are less poisonous, and all penetrate more rapidly than alkalis.

List of investigators at the laboratories of the Department of Marine Biology since 1904, their addresses, and the general scope and places of publication of the results.

[The volumes of "Researches from the Tortugas Laboratory," published by the Carnegie Institution of Washington, are referred to in Roman numerals.]

Name and address of investigator.	Time of visit to laboratory.	Subject of research.	Where published.
Ball, Stanley C., Yale University	1913, 1914	Insects of Tortugas.	
Bartsch, Paul, U. S. National Museum	1912, 1913, 1914	Effects of environment upon cerions from the Bahamas	Smiths. Misc. Collections, vol. 60, pp. 58–62, 1913.
Brooks, W. K., Johns Hopkins University	1905, 1906	Salpæ, Appendicularia, origin of lung of Ampullaria	Vol. I, 1908, two papers.
Cary, Louis R., Princeton University	1910, 1911, 1912, 1913, 1914	Alcyonaria, actinian larvæ, growth and œcology of gorgonians; regeneration in Cassiopea.	Vol. V, 1914.
Chapman, Frank M., American Museum of Natural History.	1907	Frigate-birds and boobies of Cay Verde, Bahamas	Vol. II, 1908.
Clark, Hubert Lyman, Harvard University Museum.	1912, 1913	Echinoderms of Jamaica and Torres Straits, Australia	Vol V, 1914.
Cole, Leon J., University of Minnesota	1906	Ants.	
Conklin, E. G., Princeton University	1905, 1907	Structure of eggs of Medusæ; Actinian larvæ	Vol. II, 1908, two papers.
Cowles, R. P., Manila, Philippine Islands	1905, 1906, 1908, 1909	Reactions and habits of the ghost crab and of star-fishes	Vol. II, 1908; Vol. III, 1911.
Cushman, J. A., Boston Soc. Nat. Hist.	1912	Foraminifera of Jamaica.	
Dahlgren, Ulric, Princeton University	1910, 1912, 1913, 1914	Electric organs of fishes	Vol. VI, 1914.
Dole, R. B., U. S. Geological Survey	1913	Chemistry of Tortugas sea-water	Vol. V, 1914.
Drew, Gilman A., Woods Hole, Mass.	1914	Cephalopods, habits and structure; Spermatophores.	
Drew, George Harold, Cambridge University, England.	1911, 1912	Denitrifying bacteria of sea-water and precipitation of calcium carbonate in the ocean.	Vol. V, 1914.
Edmondson, C. H., Iowa	1906	Protozoa of Tortugas	Vol. I, 1908.
Goldfarb, A. J., College of City of New York.	1912, 1913	Effects of nervous system on regeneration; Effects of concentration of sea-water; Fused echinoderm larvæ	Vol. VI, 1914, three papers.
Gudger, E. W., State Normal College, N.C.	1912, 1913, 1914	Anatomy of sharks, rays, and teleosts	Vol. VI, 1914.
Gulliver, F. P., Washington, D. C.	1914	Formation of cuspate forelands.	
Hartmeyer, R., Berlin, Germany	1907	Ascidians, echinoderms	Vol. III, 1911, and in Germany.
Harvey, E. Newton, Princeton University	1910, 1913, 1914	Effects of temperature upon rate of nerve conduction; Permeability of cells to alkalis and to acids.	Vol. III, 1911; Vol. VI, 1914.
Hooker, Davenport, Pittsburgh	1905, 1907, 1908	Reactions of newly hatched loggerhead turtles	Vol. III, 1911.
Jackson, R. T., Boston Soc. Nat. Hist.	1912	Variation and evolution of Echini	Vol. V, 1914.
Jacobs, M. H., Univ. of Pennsylvania	1911	Physiology of protozoan parasites	Vol. VI, 1914.
Jennings, H. S., Johns Hopkins University	1905	Behavior of sea-anemones	Journ. Exp. Zoology, vol. 2, 1905.
Jordan, H. E., University of Virginia	1907, 1912, 1914	Cytology; Aplopos; Echinoderms	Vol. I, 1908, three papers.
		Spermatogenesis of mongoose	Vol. V, 1914.

Jörgensen, E., Bergen University, Norway	1910	Peridinea	Various publications.
Kellner, Carl, Yale University	1905, 1906, 1907	Embryology of appendicularia	Zool. Anzeiger, Bd. 31, 1907.
Lashley, K. S., Johns Hopkins University	1913	Habits of noddy and sooty terns.	
Linton, Edwin, Washington and Jefferson College.	1906, 1907, 1908	Habits of Fierasfer; Helminth fauna of Tortugas	Amer. Naturalist, vol. 41, 1907. Vol. I, 1908; Vol. IV, 1910.
Longley, W. H., Goucher College	1910, 1911, 1913, 1914	Œcology and evolution of reef fishes with respect to color	
McClendon, J. F., Univ. of Minnesota	1908, 1910	Adaptation and structure of animals	Vol. III, 1911.
		Permeability of cells	Vol. VI, 1914.
Mast, S. O., Goucher College	1910	Reactions of Turbellaria and of turtles	Vol. III, 1911.
Mayer, A. G., Carnegie Institution of Washington.	1904 to 1914	Medusæ, Ctenophoræ, Atlantic palolo; Physiological effects of ions of sea-water; Effects of temperature; Coral reefs of Torres Straits; Starving of Cassiopea.	Vols. I, two papers; III; VI, three papers; Medusæ of the World, 3 vols.; Ctenophoræ of Atlantic Coast of North America; Pulsation in Medusæ.
Meek, Seth E., Field Museum, Chicago	1909	Reef-fishes for a group in the Field Museum.	
Osburn, R. C., New York Aquarium	1908	Bryozoa of Tortugas	Vol. V, 1914.
Perkins, H. F., University of Vermont	1905	Medusæ of Tortugas	Vol. I, 1908.
Potts, F. A., Cambridge University, Eng.	1913	Habits and reactions of crustacea of Torres Straits.	
Pratt, Henry S., Haverford College	1905	Trematodes of Tortugas	Vol. IV, 1910.
Reighard, Jacob, University of Michigan	1905, 1907	Warning coloration in reef fishes; Memory in fishes	Vol. II, 1908.
Reinke, Edwin E., Rice Institute, Houston, Texas.	1911, 1912, 1913, 1914	Development and reactions of molluscan spermatozoa	Vol. VI, 1914.
Stockard, Charles R., Cornell Medical College.	1907, 1908, 1909	Tissue growth and regeneration	Vol. II, 1908, two papers.
		Reactions of Aplopus; Reversal in regeneration of chelæ in Alpheus; Effects of regeneration on the body tissues.	Vol. III, 1911.
Stromsten, Frank A., Iowa University	1907, 1910	Vascular and lymphatic systems of turtles	Vol. III, 1911.
Tashiro, Shiro, Chicago University	1914	Production of CO_2 by animals; Studies of metabolism; CO_2 content of sea-water.	
Tennent, David H., Bryn Mawr College	1909, 1910, 1912, 1913	Hybrid Echini of Tortugas, Jamaica, and Torres Straits	Vol. III, 1911; Vol. V, 1914.
Tower, W. L., Chicago University	1908, 1909, 1910	Heredity in beetles.*	
Treadwell, A. L., Vassar College	1909, 1910, 1913, 1914	Eunicidæ of Tortugas; Reactions of the Atlantic palolo	Bulletin American Museum Natural History, vol. 30, 1911.
Vaughan, Thomas Wayland, U. S. Geological Survey.	1908, 1909, 1910, 1911, 1912, 1913, 1914	Geology of southern Florida and Bahamas; Coral reefs; Growth of corals, habits, reactions to light, food, salinity, drying in air; Studies of currents; Formation of oölite; Mechanical and chemical effects of sea-water on limestones.	Vol. IV, 1910; Vol. V, 1914, two papers. Also several papers elsewhere.
Wallace, W. S., University of Nevada	1908	Hydroids of Tortugas.	
Watson, John B., Johns Hopkins University.	1907, 1910, 1912, 1913	Reactions and habits of noddy and sooty terns; Practice curve in man and animals.	Vol. II, 1908.
Zeleny, Charles, University of Indiana	1906	Regeneration	Vol. II, 1908.

*The Tortugas proved to be an unfavorable location for these experiments.

In order to supplement certain conclusions stated in his great work on the "Phylogeny of the Echini," Professor Robert Tracy Jackson collected 2,878 specimens of echini at Montego Bay, Jamaica, and studied the changes in position of their ocular plates during the growth of the individual. He found, in conformity with his previous conclusions, that primitive and geologically ancient genera, such as *Centrechinus*, are very slow in acquiring the final arrangement of ocular plates, whereas more recent and highly specialized genera, such as *Strongylocentrotus*, have a highly accelerated development. This is in accord with Hyatt's observations on fossil cephalopods. Changes which are significant in relation to the phylogenetic status of the group occur throughout the life of the individual, as Dr. Jackson has shown both in his studies upon plants and upon echini.

Dr. Merkel H. Jacobs, basing his conclusions upon a study of the reactions of four species of parasites which inhabit the alimentary tract of one of the echini, decides that the physiological characters of an organism are not merely the result of its environment, but may be as fundamental and characteristic as its morphological ones.

Dr. H. E. Jordan came to Jamaica to study the cytology of the sex-cells of *Echinaster*, but as no ripe eggs could be obtained from these star-fishes, he studied the spermatogenesis of the mongoose, and concludes that in mammals in which an x-element is present the female sex is homozygous and the male heterozygous. Apparently the accessory chromosome acts as a deterrent to the development of maleness.

Professor W. H. Longley's researches have been referred to elsewhere in this report.

Dr. J. F. McClendon, upon testing their electrical conductivity by Kohlrausch's method, found that the permeability of echinoderm eggs to ions increases on fertilization. The unfertilized egg is perhaps in a dormant condition, and the increase in permeability probably allows a rapid interchange with the surrounding medium necessary for activity and development.

Alfred G. Mayer found that the more specialized sort of cilia, which move intermittently at regular intervals of time, are affected by the cations of sea-water in a manner which is the converse of their effects upon the neuro-muscular system. This is a mechanical, not a chemical, matter, for the cilia-bearing cells are very sensitive to pressure; hence magnesium, which relaxes the muscular tonus and relieves the skin-pressure, permits the cilia to beat at an abnormally rapid rate, whereas sodium, which causes the muscles to contract, increases the muscular tonus, and hence the pressure upon the cilia-bearing cells is increased and the cilia cease to beat.

Pressure also dulls the sensitiveness of the neuro-muscular system of *Cassiopea*, and neurogenic contraction waves always travel from unpressed to pressed regions, whether from anode to cathode or from cathode to anode, provided one electrode presses upon the tissue

while the other touches it lightly. The wave also travels from rested toward tired or from fresh toward exhausted tissue.

Magnesium is not an active inhibitor of nerve conduction in *Cassiopea*, but is nearly if not quite neutral, having little or no more effect than distilled water or a non-electrolyte, such as dextrose.

Sodium and potassium behave alike in respect to nerve conduction, but potassium is much more active than sodium, as one would expect from its higher atomic weight.

Calcium combines to form a sodium-calcium proteid which tends to produce muscular tetanus, but this tendency is offset by the effect of magnesium. Calcium can not produce tetanus unless sodium be present.

The rate of nerve conduction in *Cassiopea* is more rapid in 95 per cent sea-water than in natural sea-water. It is again about normal in 80 per cent sea-water, below which it falls off steadily.

Tropical marine animals are more injuriously affected by slight changes of temperature above or below the normal than are those of colder seas, and (as Harvey showed) the tropical forms live within a few degrees of their upper death temperature, and can withstand cooling much better than they can heating. It seems probable that the effect of high temperature is to produce asphyxiation, the oxygen of the sea-water being insufficient to maintain the increased metabolism of the animal.

A study of the coral reefs of the Murray Islands, Torres Straits, shows that temperature is the most important factor determining the habitats of the various sorts of corals over the reef flats, for, in common with other tropical marine animals, corals live within less than 10° C. of their death temperature. High temperature probably produces death by causing asphyxiation, hence those corals which are most easily affected by high temperatures are usually also those which are most easily smothered by mud and must, therefore, live in pure ocean-water free from silt, and can not survive in the hot, muddy water near shore. The physiological reactions of Australian corals are essentially similar to those of Florida, and natural selection has not improved them. For example, the Torres Straits corals withstand low temperature as well as do those of Florida, and the Florida corals are quite as well able to resist heat as are those of Torres Straits.

It appears that the rate of starvation in *Cassiopea* can be expressed by the formula $y = W\ (1-a)^x$, where y is the weight at the end of x days, W is the original weight, and a is a constant less than unity. This formula shows that the substances which sustain the starving animal remain the same throughout the period of starvation.

Professor Henry S. Pratt found a new species of trematode at Tortugas, *Monocotyle floridana*, in which the alimentary tract, at least in some individuals, is complete.

Dr. Edwin E. Reinke has made an interesting cytological and physiological study of the dimorphic male sex-cells of various prosobranch

mollusks, paying attention to their development, function, and reactions. He concludes that the large apyrene male sex-cells, which, when mature, lack nuclei, probably serve as nurse-cells for the small, active, true spermatozoa or eupyrene sperm of the mollusk. The reactions of one sort of sperm-cells are commonly the opposite of the others.

Professor Charles R. Stockard concludes that regenerating tissue resembles cancer in that it consumes the old body-substance and has an effect which would finally so weaken the body as to cause death should the regeneration continue for a sufficient time.

Dr. Frank A. Stromsten finds that in the embryo loggerhead turtle the mesenchymal spaces capture certain capillaries and convert them into the anlagen of the lymph hearts.

Professor David H. Tennent has ably pursued his studies of the characters of hybrid echinoderm larvæ at Tortugas, Jamaica, and Torres Straits, Australia. At Tortugas he showed that in natural sea-water reciprocal crosses between the two echini *Hipponoë* and *Toxopneustes* give a hybrid larva in which the *Hipponoë* characters are dominant, and this is also the case if the alkalinity of sea-water is increased by the addition of caustic soda. If, however, the alkalinity of the normal sea-water is reduced by the addition of hydrochloric or acetic acid, the hybrid larvæ resemble *Toxopneustes*. Thus Professor Tennent can, at will, cause the hybrid larvæ to resemble either their paternal or maternal parents, and has thus, in a sense, been able to artificially control dominance.

In another research at Montego Bay, Jamaica, Professor Tennent showed that when the *Cidaris* egg was fertilized with *Toxopneustes* sperm, the sperm-cell had a decided directive influence upon the rate and mode of development of the larva from the early segmentation stages onward; and while in Torres Straits, Australia, Professor Tennent discovered even more favorable material for a continuance of these studies, and he also succeeded in effecting a cross between a female crinoid and a male echinus, and in carrying the larvæ to a later stage than had hitherto been done.

The important studies of Dr. Thomas Wayland Vaughan upon the geology of limestone regions and the biology, growth-rate, œcology, and physiology of coral reefs has been in part reviewed elsewhere in this report. It will be unnecessary, therefore, to refer again to his studies demonstrating the manner in which the precipitated aragonite ooze of the Florida-Bahama region changes into oölites, nor to his contention which confirmed the previous work of Dall, 1892, and Sanford, 1910, that this calcareous ooze was a chemical precipitate, a deduction which has been fully confirmed by the studies of Drew and of Kellerman, who have demonstrated that this precipitation of calcium carbonate is due to the action of several sorts of bacteria.

Andrews showed that the submerged platform upon the seaward edge of which the Great Barrier Reef of Australia has grown and

formed a breakwater wall extends far southward beyond the region of coral reefs, and thus it can not owe its origin to corals, but must have been in existence before the corals grew upon it. Vaughan has extended this idea, showing that certainly in the Florida-West Indian region, and probably elsewhere, the modern reefs are growing upon the outer edges of submerged platforms which were formed before the corals began to grow. As is well known, Penck and also Daly have attempted to explain the origin of these submerged platforms as being due to marine corrosion when the tropical sea was lower than at present in the glacial period. Vaughan, however, has not yet committed himself respecting the origin of the platforms.

Vaughan denies that normal sea-water as such can dissolve limestone, and in this respect his views stand in opposition to those of Sir John Murray and Alexander Agassiz.

Vaughan's studies in Florida and the Bahamas conclusively show that in these regions the corals are a minor element in the composition of the great limestone banks, and the so-called "coral muds" of older authors are largely oölites which have been derived from chemically precipitated calcium carbonate.

Dr. Vaughan shows that in southern Florida Pliocene depression was followed by uplift, which was succeeded by depression in Pleistocene times. Then in late Pleistocene times there came another uplift, so that the land was more than 50 feet above its previous level. The region was then again depressed 30 feet or more. The Florida Barrier Reef developed subsequently to the beginning of this last depression seaward of the keys on a platform already prepared for it by marine erosion. The Marquesas was formed by winds and currents, and coral reefs have reestablished themselves at Tortugas after the final submergence of the group.

Dr. Vaughan's conclusions respecting the somewhat similar changes of level in the Bahamas are stated in his report published herewith.

Dr. Vaughan has made the most extensive study of the rate of growth of reef corals yet attempted, having been engaged upon these observations since 1908, but as his results have not yet been published, we are not at liberty to state his conclusions. He also carried out a number of physiological studies upon corals and showed that, in common with other cœlenterates, they feed exclusively upon animal matter. He also found that if kept in the dark the "symbiotic" plant-cells of the corals are much more injuriously affected than are the corals themselves, thus indicating that the corals are in no essential respect dependent upon these plant-cells, but that the reverse is more nearly the case. In another research he found that the more spongy or cavernated corals are better able to withstand exposure to the air, provided the base be submerged, and also that corals are not very sensitive to dilution of the sea-water.

There are many other interesting and important points in Dr. Vaughan's work, but his biological studies are, as yet, largely unpub-

lished, or are presented only in preliminary reports, and we await his final publication, which may be expected to appear within a year or two.

Working with Ekman meters, Dr. Vaughan showed that the prevailing impression is correct, that there is a decided westerly set of the surface-waters of the Hawk Channel and Tortugas region. Thus at Tortugas and for some distance to the southward, the water is moving westerly, whereas the Gulf Stream moves eastward.

It will be seen that the studies which have been pursued at Tortugas cover a wide range of subjects, from the habits of sea gulls to the geology of limestone regions; but the major efforts of the Laboratory have been directed toward experimental work in biology and physiology, for the reason that these subjects have hitherto been neglected in tropical regions. Yet with its pure water and uniform temperature, that of the water being practically the same as that of the air, the Tortugas and West Indian region affords an unique opportunity for the prosecution of experimental work. Systematic work upon dead and preserved material has not been neglected by the Laboratory, but has been relegated to a secondary place, for the reason that many such collections have already been made in the tropics, the specimens being taken to temperate regions for study. It has, above all, been the aim of the Laboratory not to undertake studies which could be prosecuted with equal success elsewhere or performed by other existing agencies. Indeed, in common with all other departments of the Carnegie Institution of Washington, we are in no sense a rival of the universities and laboratories of our country, but our highest purpose is to be of important assistance to all and to do those things which for some reason can not be or have not been done by other institutions. In each case it is the aim of the Laboratory to grant to the exceptional man the best possible facilities for the prosecution of his chosen research, and if we have succeeded in widening the range and enlarging the field of research in marine biology, it is due solely to the devoted labors of many of the most gifted young men of the college faculties of our country, who year after year have labored faithfully in the arduous task of winning at least some measure of success for an enterprise for which many predicted failure.

Moreover, and by no means least, it is a pleasure to speak of the faithful work in calm and in time of storm of the manly crew of the *Anton Dohrn*, to whom hardship and danger have been but an incentive to the cool and efficient performance of their duty.

Throughout the period of the existence of the laboratory at Tortugas, the commandants of the naval station at Key West have been most kind to us, and to Admiral George P. Colvocoresses, Commodore William H. Beehler, and Captain Edward Everett Hayden, successively commandants of the naval station at Key West, it is a pleasure and privilege to express our thanks.

REPORTS OF INVESTIGATORS FOR THE SEASON OF 1913-1914.

Insects of the Tortugas, by Stanley C. Ball.

During the period from June 18 to July 28, 1914, I made an attempt to collect, on Loggerhead Key, Dry Tortugas, as many species of insects as possible. There were two incentives to this work besides that of pleasure. First, I had learned from Dr. Mayer that, to his knowledge, no such attempt had previously been made; for this reason, and the fact that the Tortugas are the most isolated islands on the coast of the United States, it seemed possible that the insect fauna of the island might contain species not yet described. In the second place, the small size of the key and its limited number of plants lent themselves to a fairly easy and thorough examination within the time at my disposal.

All species of plant except the *Cæidea* trees set out in the lighthouse grounds were examined both by daylight and, with the aid of a bull's-eye lantern, at night. I found "beating" the method most productive of results. For this purpose an umbrella was used wherever convenient; in thick bushes and grass a small net served the purpose. Sheets of "Tanglefoot" sticky fly-paper set out on boards captured many specimens which were later dissolved off in alcohol. In the evenings, Odonata, Hemiptera, Coleoptera, and Lepidoptera were attracted to lights at the laboratory.

Three species of plants together yielded perhaps three-quarters of the entire collection. A small pusley-like plant on the beach swarmed with Diptera, Hemiptera, Coleoptera, Lepidoptera, and Hymenoptera. The extensive growth of bay cedar (*Surianum*) yielded Coleoptera, Orthoptera, Odonata, Neuroptera, and Hemiptera. Frequenting the sea-bean vines I found lesser numbers of Hymenoptera, Diptera, Hemiptera, and Lepidoptera. A small group of *Cæidea* trees was infested with immense numbers of a black beetle, which to investigators attempting to use a light in the evening proved a great nuisance. The other species were taken from such places as the seaweed along the beach, leaves of exotic plants introduced with the laboratory, and the laboratory buildings themselves. Hordes of ants and cockroaches appeared wherever any dead animal or plant matter was left.

In the table below I have noted the number of species to each order as nearly as I have been able to work them out. Doubtless in a few cases more than one species is rated as one. I have aimed rather to find the minimum. My determination shows at least 121 species.

Order.	No. of species.	Where found.
Thysanura........	1	Laboratory and under seaweed on beach.
Thysanoptera.....	1	Grape-fruit skins on beach.
Malophaga........	4	Terns (*Anous stolidus* and *Sterna fuliginosa*) and booby (*Sula leucogaster*).
Odonata......	3	Bay cedar.
Orthoptera........	5	Bay cedar, etc.
Neuroptera.......	2	Bay cedar.
Hemiptera:		
Heteroptera...	18	Small plant on beach, bay cedar, etc.
Homoptera....	7	Small plant on beach, bay cedar, lights.
Lepidoptera.......	13	Small plant on beach, bay cedar, lights.
Coleoptera........	23	Small plant on beach, bay cedar, lights, etc.
Diptera...........	29	Plants on beach, laboratory, lights, etc.
Hymenoptera.....	15	Plants on beach, sea bean, etc.
Total.......	121	

It is intended that the collection, which I have both pinned and in alcohol, shall be further worked out with a view to determining how many species are able to pass by wing from the mainland to the Dry Tortugas; how many, like *Aplopus mayeri*, are new, and how many appear to have been introduced. In the latter regard, it is interesting to note the following possibilities: Schooner loads of soil taken to Loggerhead Key from New Jersey, between 1909 and 1912, undoubtedly contained the eggs of some of the Orthoptera and possibly of other orders. Stores brought to the island certainly carry several species of Diptera. Probably many insects are carried on the boats themselves. One cerambycid beetle was discovered on the awning of the yacht *Anton Dohrn*.

Since East Key, a small island on the northeast, is the most isolated of the group, Dr. Mayer kindly made it possible, on July 18, for me to spend a day there in order to determine how the insect fauna compared with that on Loggerhead Key. It was his belief that on East Key would be found only the species which came by their own locomotion. As a matter of fact, however, three cages of rats had been landed on the island in June; in the straw which the cages contained I found a single cockroach and several crickets and beetles. Whether the latter two were introduced in the boxes or had entered after their arrival I can not say. I saw several of the crickets in other parts of the island, but none of the Coleoptera and no roaches. A fairly thorough search of East Key yielded 33 species, as follows: Odonata, 1; Orthoptera, 4; Hemiptera, 9; Lepidoptera, 1; Coleoptera, 5; Diptera, 8; Hymenoptera, 5.

Of these, 2 Coleoptera and 1 species each of Orthoptera and Diptera were not taken on Loggerhead Key.

Birds Observed on the Florida Keys from April 20 to April 30, 1914, by Paul Bartsch.

Last year a list of the birds observed, between April 25 and May 9, on the various keys between Miami and the Tortugas was published in the annual report of the Department of Marine Biology, pp. 172–175. Since these have proved of interest to ornithologists, and especially to students of bird migration, it was deemed wise to continue these observations this year, and I therefore offer the following journal extracts upon the subject. Our cruise this year was of shorter duration and somewhat earlier than that of last year, which gave the avifauna of these keys quite a different aspect from that observed then. Only 46 species were noted, while last year the total reached 57; but 19 of the 46 are additions to last year's list, which raised the whole so far observed in this region to 76.

April 20.—While walking about Miami, at 5^{h} 30^{m} p. m., the following were observed: Black-poll warbler, black-throated blue warbler, redstart, mocking bird, Florida cardinal, night hawk, turkey buzzard. Many of the warblers were too high in the trees to be positively determined without a glass. No doubt a much larger list of these might have been secured with the aid of a glass.

April 21.—Left our anchorage at 6 a. m., steaming down the channel between Miami and Cape Florida. Birds did not seem nearly as abundant as they were a year ago. We saw only a single yellow-palm warbler, 2 cormorants, and 3 royal terns flying about. Last year all the stakes marking the channel were occupied by royal terns. Rounding Cape Florida and going down Hawk Channel, we observed many flocks of small birds, all coming from the south and flying due north toward the small keys. The sky was heavily over-

cast and there was a slight breeze from the northeast. In some instances it was possible to determine the species when they were close enough. I kept the following count. All were warblers.

$7^h 15^m$,	12 Black-polls.	$8^h 14^m$,	5 Warblers (species ?).
7 45	13 Black-polls.	8 15	1 Black-throated blue warbler (male).
7 50	5 Warblers (species?).	8 19	2 Black-throated blue warblers (male and female).
7 53	3 Warblers.	8 20	12 Warblers (species ?).
7 55	1 Warbler.	8 24	10 Black-poll warblers.
8 03	6 Warblers.	8 25	26 Warblers (species ?).
8 04	19 Warblers.	8 37	3 Warblers (species ?).
8 05	15 Warblers.	8 41	14 Black-throated blue warblers.

On the second Ragged Key north of Sands Key we saw a gray kingbird, a bird not positively identified last year; also 4 yellow-palm warblers, 1 Florida yellow-throat, 1 man-of-war bird, 2 brown pelicans.

On the first Ragged Key north of Sands Key we observed redstarts, yellow-palm warblers, black-poll warblers, and a pair of Louisiana herons.

On Sands Key a savanna sparrow, a Florida cardinal, a white-eyed vireo, a redstart, and a pair of yellow-palm warblers were observed. The latter were working among the dead coral heads left exposed by the receding tide.

April 22.—No migrating birds were observed while steaming this morning. Visited Tea-Table Key, where the following birds were seen: Florida yellow-throats (quite abundant), yellow-palm warblers (very abundant), black-poll warblers (common), prairie warblers (present in large numbers), black-throated blue warbler (sparingly present), pigeon hawks, royal terns, ground doves. Warblers were simply teeming; the whole place seemed full of them. Looked especially for the red-bellied woodpecker, but saw none on this key nor on Indian Key. They were on both on April 27, 1913.

On Indian Key we saw 2 turkey buzzards, probably nesting, as they were very tame and kept coming back to see if all was well; also boat-tailed grackles (colony, not yet nesting), prairie warblers, a yellow-palm warbler. Birds on this key were not nearly as abundant as on Tea-Table Key. Toward evening we visited Knight's Key, where the following were seen: 3 ospreys (fishing), 13 brown pelicans (mostly old birds), 8 royal terns, small flock of white ibis, man-of-war birds, pigeon hawks, 2 catbirds, a Florida cardinal, a Florida yellow-throat, and a yellow-palm warbler.

April 23.—On Duck Key we saw a gray kingbird and a brown pelican. On Bahia Honda Key, boat-tailed grackles, brown pelicans, and a savanna sparrow were observed.

On New Found Harbor Key I saw a lot of warblers, but they were very shy and difficult to determine. The following positive identifications were made: Redstart (male and female), a prairie warbler, a yellow-palm warbler, a pigeon hawk, an American egret, and brown pelicans.

April 24.—On a trip through the city and along the beach to above Monticello tower, Key West, I saw the following: redstart, black and white creeping warbler, mocking bird, yellow-palm warblers (small flock), prairie warblers, Florida yellow-throat, ground dove, marsh hawk, Cape May warbler, parula warbler, Tennessee warbler, catbird, turkey buzzards, boat-tailed grackles, ruby-throated hummer, indigo, laughing gull, man-of-war birds.

April 25.—A pair of least terns were seen on the channel buoy off Mann's Key. At the Tortugas quite a number of man-of-war birds were seen hovering over the fort and a pair of sharp-shinned hawks were enjoying ærial maneuvers. There were also a few royal terns about, though not nearly as many as last year.

Bird Key is still waiting for its tern colony. The sooty and noddy terns have not yet arrived. During a walk about Loggerhead Key the following were seen: pigeon hawks (6 at one time), gray kingbird, 2 marsh hawks, a kingfisher, a herring gull (immature), a summer tanager (most brilliant I have ever seen), yellow-palm warblers, and sharp-shinned hawk.

On our way back to the fort we saw quite a number of royal terns seated on the buoys and stakes; also a pair of boobies, while an osprey was flying about over the fort.

April 26.—The immature herring gull seen on Loggerhead yesterday is on Garden Key to-day. The stakes are well occupied with royal terns, and sooty terns are flying about in rather large flocks, but they have not yet taken possession of Bird Key. On a trip down the island and around the lighthouse the following were seen: yellow-palm warbler, gray kingbird, sharp-shinned hawk, redstart, kingfisher, catbird, kingbird, and orchard oriole. To these I added the marsh hawk at noon.

April 27.—To-day the following were noted about Loggerhead Key: herring gull (same individual), gray kingbird, kingbird, yellow-palm warbler, marsh hawk, pigeon hawk, sharp-shinned hawk, brown pelican, osprey, redstart, and a kingfisher. Birds are still very scarce, the most conspicuous being the raptorine species.

Crossing from Loggerhead to Garden Key, we saw royal and sooty terns. There were quite a number of small flocks of the latter, but they have not yet taken possession of Bird Key. We also saw an osprey and a pair of boobies, probably, the same pair which occupied the same channel buoy yesterday.

At the fort about 100 man-of-war birds were soaring over the northeast end of the structure. The wall of the fort here evidently forces the stiff northeast breeze upward and the birds were resting upon the upthrust of the current. A pair of ospreys now and then joined them and also hung motionless for a while, but their restless nature did not permit them to stay there persistently, though they, too, seemed to like the experience, for they would return again and again to float for a while in this place on motionless wings.

April 28.—Visited Fort Jefferson at 6 a. m. and noted the following: man-o-war birds, pelican, osprey, catbird, yellow-billed cuckoo, sharp-shinned hawk, pigeon hawk, orchard oriole, Florida yellow-throat, yellow-palm warbler, black-crowned night heron, least tern, Cape May warbler, southern parula, warbler, and royal tern. All the passerines were in the trees and on the ground near the fort; so were the yellow-crowned night herons, osprey, and hawks. The terns were flying about the outside.

About 8 a. m. we headed for Bird Key, passing the usual royal tern on stakes and buoys. The key had been claimed by a few sooties, which were on the ground under the bushes. We saw no noddies. A yellow-palm warbler was also seen on Bird Key.

On Loggerhead we saw pigeon hawks, sharp-shinned hawks, kingbirds, a yellow-palm warbler, and catbirds.

About 3 p. m. I revisited Fort Jefferson and found the largest number of birds I have seen since we left Tea-Table Key. The yellow-palm warblers were very abundant. So were the parulas, the black-throated blue warblers, and the Florida yellow-throats. I also saw yellow-palm warblers (male and female), man-of-war birds, black-throated blue warbler, southern parula (male), prairie warblers (male and female), pigeon hawks, Florida yellow-throats (male and female), black-poll warbler (male), worm-eating warbler, oven bird, redstarts (male and female), catbirds, black-crowned night heron, Kentucky warbler (male), brown pelican, osprey, royal terns. The man-of-war birds have been hanging over the northeast corner of the fort all day, where the upthrust of the air gives them a resting place.

April 29.—Off for Key West. Passed many royal terns on the buoys and stakes and quite a number of sooties flying about. On the north side of Marquesas Key we saw royal terns, brown pelicans, osprey, American egrets, black-crowned night herons.

May 1.—Sooty terns were seen in small flocks on the way from Key West to Havana.

Scientific equivalents for the common names of birds used in the preceding list.

Herring gull = Larus argentatus.
Laughing gull = Larus atricilla.
Royal tern = Sterna maxima.
Least tern = Sterna antillarum.
Sooty tern = Sterna fuscata.
Red-footed booby = Sula piscator.
Cormorant = Phalacrocorax auritus floridanus.
Brown pelican = Pelecanus occidentalis.
Man-of-war bird = Fregata aquila.
White ibis = Guara alba.
American egret = Herodias egretta.
Louisiana heron = Hydranassa tricolor ruficollis.
Black-crowned night heron = Nycticorax nycticorax nævius.
Ground dove = Chæmepelia passerina terrestris.
Turkey buzzard = Cathartes aura septentrionalis.
Marsh hawk = Circus hudsonius.
Sharp-shinned hawk = Accipiter velox.
Pigeon hawk = Falco columbarius columbarius.
Osprey = Pandion haliætus carolinensis.
Kingfisher = Ceryle alcyon.
Night hawk = Chordeiles virginianus virginianus.
Ruby-throated hummer = Archilochus colubris.
Kingbird = Tyrannus tyrannus.
Gray kingbird = Tyrannus dominicensis.
Boat-tailed grackle = Megaquiscalus major major.
Orchard oriole = Icterus spurius.
Savanna sparrow = Passerculus sandwichensis savanna.
Florida cardinal = Cardinalis cardinalis floridanus.
Indigo = Passerina cyanea.
Summer tanager = Piranga rubra.
White-eyed vireo = Vireo griseus griseus.
Black and white creeping warbler = Mniotilta varia.
Worm-eating warbler = Helmintherus vermivorus.
Tennessee warbler = Vermivora peregrina.
Parula warbler = Compsothlypis americana americana.
Cape May warbler = Dendroica tigrina.
Black-throated blue warbler = Dendroica cærulescens cærulescens.
Black-poll warbler = Dendroica striata.
Yellow-palm warbler = Dendroica palmarum hypochrysea.
Prairie warbler = Dendroica discolor.
Oven bird = Seiurus aurocapillus.
Kentucky warbler = Oporornis formosa.
Florida yellow-throat = Geothlypis trichas ignota.
Redstart = Setophaga ruticilla.
Mocking bird = Mimus polyglottos polyglottos.
Catbird = Dumetella carolinensis.
Yellow-billed cuckoo = Coccyzus americanus americanus.

Preliminary Report on the Bahama Cerions Planted on the Florida Keys, by Paul Bartsch.

The colonies were visited this year between April 21 and 30, and found in the following condition:

Second Ragged Key north of Sands Key	Good.
First Ragged Key north of Sands Key	Good.
Tea Table Key	Probably extinct.
Indian Key	Very poor.
Duck Key	Undecided.
Bahia Honda Key	Very good.
New Found Harbor Key	Almost extinct.
Boca Grande Key	Good.
Garden Key	Almost extinct.
Loggerhead Key, Tortugas	All very good.

Two new colonies of cerions from the Bahamas were started this spring on Loggerhead Key, Tortugas, Florida. One of these consists of 500 of the "King Road type," from Andros Island, and the other is composed of 200 specimens of "mottled cerions" from Spring Hill, about 6 miles ESE. of Nassau, New Providence, Bahama. Besides these two new colonies, a planting of young

Florida-grown specimens was made on the Second Ragged Key north of Sands Key, on Sands Key, Bahia Honda, and three on Loggerhead Key, Tortugas.

Adult specimens of the first generation were found on the Second Ragged Key north of Sands Key, on Bahia Honda Key, on Boca Grande Key, and on Loggerhead Key. These adult specimens of the first generation of both races of Florida-grown individuals now enable us to say that a decided change has taken place—that the first generation is not like the parent generation, and that the departures, in some instances, are so pronounced that the specimens would easily be considered distinct species and probably deemed not very closely related to the parent stock by workers in this group, unfamiliar with the history of the material. Moreover, the range of variation in the offspring is wider than that of their parents.

A complete report upon the work so far done, and the results obtained in these experiments, will shortly be published.

Report on Investigations at Tortugas, by L. R. Cary.

STUDIES ON ALCYONARIA.

Growth Rate.

The records of the growth rate of several species of gorgonians have been continued, both by means of measurement and photographic records of specimens cemented on tiles, as well as by the annual measurement of individuals growing in their natural positions on the reefs. These records now extend over a period of five years, for some species, and cover the growing period from the attachment of the planulæ to the attainment of the full size of the colony.

In one instance it has been possible to observe the reestablishment of the gorgonian fauna over a considerable reef area on the southern end of White Shoal. This portion of the reef was brought above low-water mark during the hurricane of October 1910, so that in January 1911 an area of 2 acres or more was exposed. By June 1911 the easily moved material had been washed from the summit of the reef, so that it was permanently below low-tide mark. This washing of the lighter unattached material continued, so that by the summer of 1912 the surface of the reef had reached its final level. At this time no gorgonians were found at any place on the reef that had been subjected to the heaping up and subsequent removal of the light material by wave action. In September 1913 many small specimens of *Gorgonia acerosa* were noticed on the reef, but no accurate record of their numbers was made. When counts were made in July of this year an average of 3.7 individuals was found for each square yard as determined from 75 counts. Nearly all of the specimens were 2 years old and at least 95 per cent of all those growing on the new part of the reef were of the single species *G. acerosa*. Farther to the north, on the deeper part of the same reef, several other species of gorgonians are more common than the above-mentioned form, but for some reason the planulæ of *G. acerosa* only had secured attachment in positions favorable for continued growth.

The planulæ of *Briareum* sp. were set free in great numbers from colonies brought into the laboratory, and readily underwent their attachment and transformation to form the polyp-bearing colony.

As complete a collection as possible was made of the alcyonaria from the region about Tortugas on both the shallow and deeper reefs. All the forms secured were photographed and notes were made of their characteristics while living. The results of this work, when combined with those of similar studies at other points in the Florida-Antillean region, will be incorporated in a systematic account of the alcyonaria of the section.

THE ALCYONARIA AS A CONTRIBUTING FACTOR IN CORAL-REEF FORMATION.

Among the alcyonaria, representatives of those families alone—Tubiporidæ, Helioporidæ, and Corallidæ—which form a massive skeleton are the only ones which have received any serious attention as contributing actively to the accumulation of calcium carbonate in coral-reef regions. The remaining Alcyonaceæ and Gorgoniaceæ—the so-called flexible corals—have been in general neglected from this point of view, although in many regions they are the only representatives of the alcyonaria occurring on the reefs.

Since practically all alcyonaria are restricted to hard bottoms, their distribution in the Florida-Antillean region corresponds to that of the coral-bearing reefs, so that the calcium carbonate accumulated in their spicules will be deposited directly on the growing reef. The spicules will, in any case, be set free only after the disintegration of the organic tissues of the colony, but the almost universal presence of such spicules in bottom samples taken over the surface of the reefs shows that they must remain on the bottom for some time without undergoing marked erosion.

In order to determine the amount of calcium carbonate held as spicules in the tissues of gorgonian colonies, specimens of the 10 forms occurring in greatest abundance about the Tortugas were collected, weighed while still wet, and the organic matter of the colony disintegrated by treatment with a strong solution of caustic soda. After repeated washings in rain-water the clean spicules were collected on a weighed filter, dried at 100° C. in a water-bath, and their weight determined. By this procedure both the actual amount of spicules and their proportion to the fresh weight of the colony was determined. The percentage of spicules in reference to the fresh weight of the entire colony made it possible to estimate with a fair degree of accuracy the amount of calcium carbonate held as spicules in any given mass of fresh gorgonians.

The following table gives the percentage by weight of spicules for 10 of the most common forms of gorgonians found about Tortugas, as determined by averaging five analyses:

Percentage of weight of spicules to fresh weight of gorgonians.

Species of gorgonian.	Percentage of spicules.	Species of gorgonian.	Percentage of spicules.
Eunecia rousseaui	35.60	Briareum sp	26.66
Plexaura flexuosa	32.27	Gorgonia flabellum	22.33
Plexaura crassa	21.45	Gorgonia acerosa	20.08
Plexaurella dichotoma	35.86	Leptogorgia virgulata (?)	25.83
Plexaurella sp	24.94	Gorgonia sp	35.05

Collections of the gorgonians were made on several reefs in water sufficiently shallow to permit wading, and separate determinations were made of the total weight of the mass taken from one square yard and that for each of the component species. The spicule content was determined separately for each species, either by direct analysis or by multiplying the fresh weight of the colonies by the percentage of spicules previously determined by several analyses of the same species. In deeper water a square frame, made from iron pipe with sides one yard in length, was lowered to the bottom and the specific identity, number, and size of the gorgonians determined by use of a water glass. On the shallow reefs the number of gorgonians found on a square

yard varied from 0 to 32, while their weight varied from 0 to 36.5 pounds. The number and weight of the gorgonians with their spicule content growing on a single dead coral (*Meandra*) head 26 inches in diameter is shown in the following table:

Gorgonians from a single coral-head.

Species of gorgonian.	No.	Weight.	Weight of spicules.
		pounds.	*pounds.*
Gorgonia acerosa.....	2	5	1.00
Gorgonia flabellum....	10	2	0.44
Plexaura flexuosa.....	10	14	4.51
Plexaura crassa.......	2	3	0.64
Eunecia rosseaui......	3	1	0.35
Total.........	27	25	6.94

In order to obtain an estimate of the number of gorgonians over a large reef area a line was run west-northwest from the laboratory on Loggerhead Key, starting from the inner edge of the living reef, in about 1 fathom of water, extending across the reef and down its outer slope to a depth of 6 fathoms. Casts of the frame, a square yard in area, were made about every 30 feet so long as the depth of water allowed of the determination of the specific identity of the gorgonians with any certainty. Farther out, where the number only of all the forms except *Gorgonia acerosa* and *G. flabellum* could be determined, the casts were made from 50 to 60 feet apart. Along this line, which was approximately 0.35 of a mile in length, in only 8 of the 45 casts did the square fall on an area of bottom where no gorgonians were attached. The largest number in any square counted was 17, and the average for the 45 casts was 5.72. Counts by means of the square-yard frame were made on nearly all of the reefs about Tortugas over which the water was sufficiently shallow to permit of the identification of the gorgonians. In many instances the counts were continued down the slopes of the reef until soft bottom was reached or the water became too deep for accurate counting. On the crests of the reefs the proportion of squares where no gorgonians were found was in no case higher than 1 to 10. The proportion of 1 to 5.6 for the long line previously mentioned was due to the fact that on the outer and deeper portion of the reef the gorgonians occurred in scattered patches over a sandy bottom. The average of the determinations of the calcium carbonate (spicule) content of the gorgonians from 20 square yards taken at random from the crests of several reefs, where all of the gorgonians were removed, and the weight of their spicules determined was 2.122 pounds per square yard or 5.28 tons per acre.

These determinations show that on many of the reefs in the Tortugas group the gorgonians are secreting an amount of calcium carbonate in their spicules far in excess of that secreted by any other organisms (corals, mollusks, or calcareous algæ) living on the same reef. At present, however, sufficient data are not at hand to warrant an estimate of the rate at which this material is actually added to the reef by the disintegration of the organic matter of the gorgonian colonies and consequent liberation of their spicules. The facies of the alcyonarian fauna on the reefs where studies on the ecology and growth rate of these forms have been carried on for five years past has remained practically unchanged during this period, except for the marked effects of the hurricane of October 1910. At this time one section of reef south of Bush

Key was noted where there were 75.7 dead gorgonians to the square yard over a considerable area. On the basis of the analyses recorded above, this would mean the deposition of at least 25 pounds of spicules per square yard and probably a considerably larger amount, as all of the dead specimens were of large size. Under normal conditions a considerable number of the axial skeletons of dead colonies are present on the reefs, but the rate of disintegration of this portion of the colony is not sufficiently well known to the writer to afford the means of ascertaining how long such a colony has been dead, which would make possible an estimate of the amount of material actually added to the reefs by the gorgonians.

Studies on Regeneration: The Influence of the Sense-Organs on the Rate of Regeneration in Cassiopea xamachana.

A series of experiments carried out at the Tortugas Laboratory during September 1913 showed that when the sense-organs were removed from one half of a *Cassiopea* disk, an equal amount of tissue from between the sense-organs on the opposite side, and the two halves insulated by the removal of two narrow strips of subumbrella ectoderm from between them, regeneration took place more rapidly from the half that bore the sense-organs. The rate of regeneration was measured inward from the periphery of a circle where the tissue had been removed from the center of the disk.

These experiments showed further that if only a single sense-organ was left on one half of a medusa disk the regeneration was faster from that side and was, indeed, as rapid as though the 8 sense-organs normally present had been left intact.

No time was then available to carry on further experiments and the data at hand seemed to me to indicate that the muscular activity and consequently higher rate of metabolism of the half disk bearing sense-organs was directly responsible for the higher rate of regeneration.

During the summer of 1914 experiments involving some 500 medusa disks, prepared so that one half was active, the other inactive, have confirmed the previous results.

Disks prepared in the manner mentioned above were allowed to regenerate in sea-water to which had been added 15 parts of 0.6*m*. $MgSO_4$. In this medium the disks continue to live and regenerate, but are unable to pulsate. Under these conditions the rate of regeneration was equal from both halves of the disk, although slower than in normal sea-water. Other individuals were treated with varying concentrations of oxalic acid which will destroy the sense-organs. In practically all instances, however, when either the concentration of the acid was high enough or the time of exposure to lower concentrations long enough to destroy the sense-organs, the other tissues of the medusa were irreparably injured, so that these experiments were of no value.

In order to eliminate the sense-organs and still retain muscular activity in one half of the disk, all sense-organs were removed, the halves insulated by removal of a strip of subumbrella ectoderm, and a trapped wave of contraction maintained in one half of the disk. This was accomplished in the manner previously described by Mayer, by so cutting the subumbrella tissue that when the contraction wave is started by induction shocks it is transmitted through an endless labyrinth of muscle tissue. After a short time the contraction wave assumed about the normal rate of pulsation of the uninjured medusa. By going over the specimens daily and cutting again wherever the wound had healed over, the stimulated half could be kept active for several days until the regeneration of the central cavity was completed. In all the specimens

treated in this manner the regeneration was equal from both halves of the disk. As in the experiments with sea-water to which had been added 15 parts of 0.6*m*. $MgSO_4$, regeneration was markedly slower than from the active side of a specimen with one-half its sense-organs.

In both the magnesium-treated specimens and those in which one half was in contraction by means of a trapped wave, the absence of the tropic influence of the sense-organs allowed the rate of regeneration to fall to that usually shown by the inactive side of a specimen, one half of which retained its sense-organs.

Report on Work at the Torres Strait Laboratory, by Hubert Lyman Clark.

When the invitation was given me to become a member of the Torres Strait expedition, I accepted with the hope that it might be possible to follow out two lines of research: one was a study of the habits and reactions of living crinoids under natural conditions, while the other was a general survey of the echinoderm fauna of the Torres Strait region. Conditions at Thursday Island proving unfavorable, it was most fortunate that Dr. Mayer decided to go at once to the Murray Islands, since they proved to be an ideal situation for the work. On the way thither, a 3-days stay at Erub (Darnley Island) gave a glimpse of the fauna there, which, while similar to that at Maër Island, shows some characteristic features of its own. On our return to Thursday Island, an opportunity to visit Badu (Mulgrave Island), 25 miles to the north, proved rewarding, several species of echinoderms not seen at Maër or Thursday Islands being found there.

Crinoids were so abundant at Maër Island and so easily obtained that it was possible to observe their habits under normal conditions as well as under the artificial conditions of the laboratory. It was found that differences of habit between different genera were most marked; representatives of some genera are very active, while others are very sluggish. Some move chiefly by swimming, while others can hardly be induced to swim under any conditions. There are also, as might be expected, great individual differences in both normal and artificially induced movements. It was interesting to find that, in spite of their fragile appearance and delicate structure, most species are quite hardy and for some time endure marked changes in environment and almost any amount of handling by the investigator. As crinoids are not available for observational or experimental work anywhere on the coasts of America or in the West Indian region (occurring there only in deep water), this opportunity to study them in their natural home was most welcome. A report on the results of the investigation is now in press.

The purpose of studying the composition of the echinoderm fauna of Torres Strait is to throw light not merely on the origin of the marine fauna of Australia, but more especially on the origin of the littoral fauna of the South Pacific islands. It is quite likely that accurate knowledge of the origin and history of the echinoderm fauna of the South Pacific islands would give us new and important light on the history of the Pacific Ocean and its islands. There are three entrances by which the fauna of the Pacific may have come from farther west: one between Japan and the Philippine Islands, one between the Philippines and New Guinea, and one between New Guinea and Australia. Careful and thorough study of the fauna of these three areas promises, therefore, some interesting and important results.

The echinoderm fauna of Torres Strait has been partially made known by the collections of the *Challenger* and of the *Alert*, to which the collections made in the vicinity of Thursday Island, in 1899, by Dr. Richard Semon, must also be added. Up to the time of our visit, 117 species of echinoderms had been

recorded from the Torres Strait region. We collected at Maër alone 151 species and at Thursday Island and Badu 26 others, not taken at Maër. Of the 117 species previously known, we found only 42, so that there are now known from this limited area not fewer than 250 species of echinoderms. In our collections there appear to be at least 45 species not previously known to science. There is abundant evidence that this extraordinarily rich fauna is not by any means yet fully known. We were so unfortunate as to lose our dredge after a single haul, and although we made several attempts to use a tangle, and on one occasion had a Japanese diver working in 18 fathoms, the results were meager. Our collections are therefore exclusively littoral in a very narrow sense. Dredging in deeper water will certainly reveal additional species. But not even the very littoral fauna is fully known. It is an actual fact that every day on the reef at Maër revealed species of echinoderms not previously seen, and on the last day at the island, after five weeks of continuous search, no fewer than four species were found which had not been noted before! These facts furnish abundant evidence that the littoral echinoderm fauna of Maër is extraordinarily rich, very possibly one of the richest in the world.

Thanks to the kind foresight of Dr. Mayer, Mr. E. M. Grosse, of Sydney, accompanied us to Torres Strait as artist, and devoted his time exclusively to the making of colored drawings, from life, of the more interesting echinoderms. It would be difficult to exaggerate the success of Mr. Grosse's work. No artist could have been more interested, willing, and industrious than he, while more than 100 beautiful figures furnish abundant evidence of his skill. It was a remarkable piece of good fortune to secure the services of such a man. The figures will be used in the illustration of a complete report on the echinoderms of Torres Strait.

I desire to express my gratitude to the authorities of the Museum of Comparative Zoology for granting me the necessary leave of absence for so long an excursion, and to Mr. Etheridge, Curator of the Australian Museum, Sydney, for much assistance, without which I should have been seriously handicapped.

The Habits of Astroscopus and the Development of its Electric Organs, by Ulric Dahlgren.

Strong efforts have been made by the writer for the last 5 years to secure suitable embryonic and larval stages of the fish *Astroscopus* in order to study the origin and development of the peculiar electric organ found under each eye. The fish is considered rare by naturalists, but continuous work in the neighborhood of Norfolk, Virginia, on its habits and the methods of its capture, indicate that it is not as rare as was thought. Over 200 specimens, ranging from 3½ inches to 21 inches in length, were secured in one season of about 8 months.

When the necessity of securing embryos became apparent, a special study of breeding habits, etc., was undertaken. A clew to the breeding habits and early development of the fish was sought by comparison with some of its nearly related forms. The habits of *Opsanus* and *Porichthys* are well known; both lay a few large eggs in "nests" of various kinds, and these eggs developed slowly into large embryos. No help was forthcoming here, and it was feared that perhaps a nest was made deep in the sand and in deep water, where the young would be nearly inaccessible. A study was then made of the ovaries and testes of large fishes at various times of the year. At first only fish from inside Chesapeake Bay were examined. These ran up to as long as 13 inches

and at no season was the roe ever found with ripe eggs. Finally a few fish were found with ripe ovaries, but all very large, over 15 inches in length, and all from pounds set out at sea off Cape Henry and Virginia Beach. This was in the spring. The ripest ova were studied and, from the size, transparency, oil drops, etc., it was decided that the early development was pelagic and that it took place in the spring and summer.

While in Naples, Italy, Dr. A. Cerruti, of the Zoological Station, very kindly gave me his information, collected at periods during many years and with unusual facilities, concerning the breeding habits of *Uranoscopus scaber*, an allied form which so closely resembles *Astroscopus* in external form and color that the average non-professional person can not tell the two apart. Also, its habits of life coincide with those of *Astroscopus*, although it has no electric organ.

As explained by Dr. Cerruti, *Uranoscopus* lays a pelagic egg which at once floats from the bottom, where it is deposited, to the surface, where it rapidly forms an embryo that lives on the surface for many weeks and months. The young fish attains a considerable size while living here, the largest one caught by the station's tow-nets being over 30 mm. in length and being a very solid, heavy fish for this length. It looked much like the adult in general, although one could see that it was distinctly larval in structure and color.

It was now hoped that the same was true of *Astroscopus* and extensive towing work was undertaken in an effort to secure the desired stages. Also, through the kindness of Dr. Henry Bigelow, of the Museum of Comparative Zoology at Harvard University, and of Dr. W. W. Welsh and Dr. L. Radcliffe, of the U. S. Bureau of Fisheries, the results of towing by the steamer *Fish Hawk* and schooner *Grampus* were examined, and from all these sources a few embryos of different sizes were secured, from which the general course of development of the electric organ can be worked out.

The life history of this fish can be described very roughly as follows: They inhabit the Atlantic Coast of America, from the neighborhood of New York south. Two species have been described, *guttatus*, north of Cape Hatteras, and *y-græcum*, south of Norfolk, Virginia. It seems to the writer, however, that these are varieties which interbreed whenever they come in contact. The southern limits of the form are not defined. It is found on the Gulf shores and the eastern coast of Panama. A third species is found on the Pacific coast of Panama and Mexico.

On the Delaware and Virginia coasts the fish is most abundant in the larger bays and sounds, from very small up to 12 to 13 inches in size; on the outer beaches, from small up to over 20 inches in size. During the winter they are "bedded" or very quiet, but when spring comes, all fish of breeding size, which appears to be over 15 inches long, work offshore and the eggs are laid at sea and float to the surface. This probably occurs in May and June and possibly is continued to a much later period. Further south it occurs earlier and may be as early as January and February in Florida and the Gulf of Mexico.

The egg is one of the largest pelagic fish eggs and rapidly hatches, yielding a young larva of short, stubby build, with much black pigment. This larva lives on the surface, well offshore (5 to 60 miles), for a period of several months, growing to a length of over 30 mm. and gradually working inshore. The form and color of this larva in its older stages make it readily recognizable as a young *Astroscopus*.

Toward the latter part of the summer the young fish, now over an inch in length, move from the surface down to the bottom and seek the sand, in which they burrow and spend the rest of their lives. One fish was taken which

possibly and probably represents this stage. It was 33 mm. long and was taken from the stomach of a sea bass (*Serranus*) off the North Carolina coast. The bass had probably taken it on its way down to the bottom or shortly after its arrival there.

As the season passes into fall the young of *Astroscopus* seek the beaches and pass into the bays and sounds. At this time they show a tendency to "school" together, as shown by their capture in the seine in groups of from 2 to 30 or more, late in the fall, when they are not over 2½ inches in length. After a short winter rest they appear again sometimes in "schools," sometimes alone, and have reached a length of from 2 to 3½ inches in April. One was captured at Beaufort, North Carolina, by Miss Rowena Radcliffe after it had attempted to swallow a *Fundulus majalis* that was longer than itself.

During the next year the fish attain a length of 4 or 5 inches, and even when 6 or 7 inches long they show the tendency to "school," being caught in company with others of about the same length.

In this history of its general seasonal movements the fish compares almost exactly with several other bottom fish of our coast, as the lump-fish, the various puffers, and many others.

The development of the electric organs is late and only really begins when the fish starts for the bottom. Enough of it has been seen to say that the organ consists of tissues that have formerly been a part of at least three of the eye muscles on each side, the edge of the muscle in each case going through peculiar changes and separating from the main muscle mass while it hypertrophies into elements many times larger than the remaining muscle fibers.

Summary of Work on the Fishes of Tortugas, by E. W. Gudger.

The work of former seasons on the fishes of Tortugas and surrounding parts was continued during my stay at the Laboratory in the month of July.

Among sharks two specimens of *Hypoprion signatus*, male and female, were taken in Key West Harbor at the same spot and at an interval of only a few hours. They were probably mates, for it is believed that selachians go in pairs, male and female. This shark, the writer believes, is new to the waters of the United States.

Two female specimens of the dusky shark, *Carcharhinus obscurus*, were taken at Key West, but neither carried embryos. These sharks are sluggish and inert and hence are easily run down and harpooned.

A 10½-foot specimen of the more active tiger shark, *Galeocerdo tigrinus*, was harpooned after a hard chase. It offered great resistance and seized the stem of the launch in its jaws, holding on until its snout had been severely cut with repeated blows of a hatchet. It finally tore loose from the harpoon, but its escape was prevented by a lashing around the small of the tail. This shark abundantly justified its name by the fierce resistance it offered and, like three others captured by the writer, showed a marked disposition to roll itself up in the harpoon line. This habit was corroborated by a number of Key West fishermen who were interrogated separately.

Two or more shark hooks were kept baited at Loggerhead and Garden Keys, Tortugas, but, though numbers of sharks were seen off the laboratory and in the lagoon of the atoll, only one was hooked. However, baits were regularly taken and several fish were evidently caught but got away, as was evidenced by the straightened-out hooks.

A *Hypoprion brevirostris* was securely hooked, but when I went out to bring it in I found only the head and shoulder parts; the remainder of the fish had been eaten by a larger shark which had been seen by one of the laboratory

attendants but a short time before, swimming around near the buoy to which the hook was attached. This incident gives an idea of the voracity of these powerful beasts.

In studying the teleosts, I was fortunate in being able to work in conjunction with Dr. W. H. Longley, who is making a study of the colors of fishes. With an excellent equipment of traps and nets, together with the use of dynamite, a larger number than ever of teleosts was taken. These were carefully identified and then dissected, and their external and internal morphological characters were studied. Considerable data was recorded along these lines, bearing on the natural history of these fishes.

A number of forms was taken, hitherto rare in the Tortugas, some which have not heretofore been reported from the waters of the United States, and one or more which apparently are new species.

Somewhat notable was the capture, on shark hooks, off the sally-port of Fort Jefferson, of two huge jewfish, *Promicrops guttata*. The smaller was 5½ feet long; the larger was 7½ feet long, 4½ feet in girth, and weighed over 300 pounds, the limit on the spring balance used for weighing fishes. At the opposite extreme for size was a little *Echeneis*, or shark-sucker, only 4 inches long, taken from a barracuda. This is one of the smallest on record.

Report of Researches conducted at Murray Island, Torres Strait, during September and October 1913, by E. Newton Harvey.

I. The Permeability of Cells for Acids.

My object in joining the Great Barrier Reef expedition was to obtain a holothurian, *Chridota purpurea*, containing a red pigment, a natural indicator for acids and alkalies. This form was collected by the Agassiz South Pacific expedition of 1899 on Wailangilala Atoll in the Fiji group and has been reported from various places in the South Pacific, so that the probability of its occurrence on the reefs of Torres Strait was strong.

Unfortunately, I was unable to obtain this species, but found another holothurian, *Stycopus ananas*, the "prickly fish" of the beche-de-mer industry, which contains a similar dark-red indicator, and has afforded some interesting results. The pigment occurs in irregular sacs in the epithelium of practically all the internal organs. It is especially abundant on the gonads, although the eggs and sperm are colorless, so that the relation between penetrability and toxicity could not be determined, as in my work with alkalies.[1] On cytolysis, by chloroform-saturated sea-water or fresh water or acid or alkali or heat, the pigment escapes from the tissue and dissolves in sea-water, just as do other pigments on cytolysis of the cell in which they are contained. It is therefore the *living* tissues whose permeability we are studying in the experiments herein recorded.

Table 1 gives the penetration times for a strong (HCl) and a weak (butyric) acid at various concentrations into living and dead (killed by chloroform-saturated sea-water) testis epithelium. The acids were always dissolved in artificial sea-water[2] (100 NaCl + 2.2 KCl + $2CaCl_2$+10 $MgCl_2$ of $\frac{m}{2}$ concentration), with the exception of oxalic acid, which precipitates as Ca oxalate, and was therefore dissolved in $\frac{m}{2}$ NaCl. The pigment changes from dark red in neutral to orange in acid solution.

[1]Carnegie Inst. Wash. Pub. No. 183, and Journ. Exp. Zool., Vol. 10, 507, 1911.
[2]Quart. Journ. Microsc. Soc., 17, 5, 1877.

It will be noted that the living cell offers considerable resistance to the entrance of both of these acids as compared with the dead cell. A large series of other acids were also studied and the relative time for penetration from

TABLE 1.

Concentration of acid.	Hydrochloric acid.		Butyric acid.	
	Living epithelium.	Dead epithelium.	Living epithelium.	Dead epithelium.
$n/20$	3 to 4 mins	Instantly	30 secs	Instantly.
$n/40$	6 to 7 mins	do.	15 mins	Do.
$n/80$	10 mins	do.	45 mins	Do.
$n/100$	12 mins	do.	50 to 60 mins	Do.
$n/160$	20 to 25 mins	do.	2 hours	Do.
$n/320$	45 mins	30 secs	4 hours	1 min.

$n/100$ and $n/200$ concentration was determined. In table 2 the series of acids so obtained is compared with their various physical properties, degree of dissociation, effect of lowering the surface tension of water, diffusion constants, and lipoid solubility. In this way an idea may be gained of the property on which rapid penetration of an acid depends. The toxicity of the acids for the

TABLE 2.

Penetration rate into tissues of "prickly fish" from $n/100$ concentration.		Toxicity to cilia of giant clam.[1]		Strength of acid. Percentage dissociation at $n/128$ concentration.		Lipoid solubility. Partition coefficient between xylol/water.		Capillary activity. Surface tension of n and $n/4$ conc., where water = 7.3 Mg-Mm.		
	Benzoic,	$n/2500$	Salic.		Nit.*	2.5	Bens.	n	$n/4$	
½ min.	Salicylic,		Bens.	.96–.99	Hydroc.*	1.3	Salic.	?	?	Bens.
	Valeric (iso-),	$n/1666$	Monoc.		Tric.	0.6	Val.	?	?	Salic.
	Monochloracetic,		Dic.		Sulph.*	0.1	Buty.*		3.56	Val.
2–4 min.	Dichloracetic,	$n/1111$	For.	.88	Dic.	0.02	Prop.*	3.30	4.39	Buty.*
	Trichloracetic,		Tric.	?	Oxal.*		Monoc.[2]	4.82		Tric.
	Formic,	$n/1000$	Sulph.*	?	Phos.*	0.015	Dic.[2]	4.82	6.13	Prop.*
	Nitric,		Tart.*	.67	Maleic*		Tric.[2]	5.20		Dic.
	Hydrochloric,	$n/909$	Val.*	.58	Malon.*	0.005	Maleic*[2]	6.00		Monoc.
9–11	Sulphuric,		Nit.	.35	Monoc.			6.04	6.81	Acet.*
	d-Lactic,		Hydroc.		Fum.				7.07	Malon.*
	l-Lactic,		d-Lac.		Tar.				7.11	Maleic*
	Fumaric,		l-Lac.	.30	Salic.*			6.83	7.14	For.
12–15	Oxalic,		Fum.		Cit.				7.17	Malic*
	Glycolic,	$n/833$	Glyc.	.20	Malic				7.24	Glyc.
20	Maleic,		Maleic		Form.*			7.19	7.27	Nit.
	Malonic,		Malon.	.13	Glycol.			7.25	7.28	Hydroc.
30	Tartaric,		Malic		d-Lac.			7.27	7.30	Sulph.
	Phosphoric,		Cit.		l-Lac.				7.27	Oxal.
	Malic,		Acet.	.08	Benz.*			7.27	7.29	Tart.
40	Citric,	$n/769$	Prop.		Val.*				7.27	Cit.
	Acetic,		Buty.		Acet.					
45–60	Propionic,	$n/400$	Phos.*	.04	Prop.					
	Butyric,				Buty.					

[1]Concentration which just kills in 20 hours.
[2]Insol. in xylol from $n/100$ conc. in water but slightly soluble from $n/10$ conc. Remaining acids insoluble from $n/10$ conc. in water. From unpublished experiments.

cilia of the palps of the giant clam, a common bivalve mollusk of the Murray Island reefs, is also included. Acids out of place as compared with the series for penetration rate are marked with an asterisk. If the tissues have previously been killed, every acid penetrates practically instantaneously in $n/100$ concentration.

From the data above recorded, we are justified in drawing the following conclusions:

Living cells are resistant to the entrance of all acids, with the exception of salicylic and benzoic and possibly valeric. The degree of resistance varies with the acid and is not nearly so marked as in alkalies.

Dead cells are permeable for all acids.

There is no relation between the degree of dissociation of the acid and its rate of penetration or between degree of dissociation and toxicity.

There is a general relation between penetrability and solubility in xylol and surface-tension lowering, but it is not exact and not quantitative.

The best relation is between penetrability and toxicity. The acids which penetrate most readily are most toxic, irrespective of their strength.

With acids, as with alkalies, lipoid solubility[1] appears to be a determining factor in penetrability. If the acid is soluble enough in fatty substances, it encounters no resistance at the cell surface. If it is lipoid insoluble or only slightly soluble, the normal cell surface must be destroyed before it can enter. The strength of the acid and possibly also a specific action of the anion on the surface proteins will then determine its rate of entrance, or, better, its rate of alteration of the cell surface.

II. Cell Permeability for Alkalies.

The permeability of marine tissues for three additional[2] alkalies was determined, making use of the neutral-red method.

(*a*) Lithium hydroxide (LiOH) behaves as NaOH, as shown in the following table, which gives the times for color changes in various concentrations in Mg.-free sea-water.

Concentration of LiOH.	$n/10$.	$n/20$.	$n/40$.	$n/80$.	$n/160$.
Ulva fronds...............	30 secs.	2 mins.	7 mins.	16 mins.	3 hrs.
Eggs of Holothuria coluber...	1 min.	4 mins.	7 mins.	28 mins.	3 hrs.

There is no return of the red color in sea-water.

(*b*) Piperidin behaves as does NH_4OH and the amines. The same tissues were tested and found to become yellow in $n/250$ piperidin in 1 minute. The red color returns promptly on return to sea-water.

(*c*) Piperazin penetrates only in relatively strong concentration, viz:

Concentration.	$n/40$.	$n/80$.	$n/160$.	$n/250$.
Time for color change.......	3 mins.	6 mins.	18 to 25 mins.	18 hrs.

The red color returns very slowly in sea-water.

[1]Or surface tension. It is possible, as Traube holds, that ability to lower the surface tension of water is the determining factor in penetration of cells.

[2]See Harvey, E. N., Carnegie Inst. Wash. Pub. No. 183.

III. CHEMISTRY OF PIGMENT OF THE BLUE STARFISH.

In the surface cells of the blue starfish (*Linckia lævigata*) there occurs a blue pigment, diffuse throughout the cells and also in the form of large darker blue granules, which has the peculiarity of turning red in alcohol and dissolving. Many crustacea contain the same sort of pigment. The surface of a large number of dried starfish was filed away and the blue powder was preserved for ultimate purification and analysis of the pigment. Only a few preliminary observations have thus far been made.

In acetone, ether, chloroform, $n/5$ NaOH, and alcohols, the red compound is formed; in glycerin, 40 per cent formaldehyde, and $n/5$ HCl, the blue compound remains unchanged.

In water, the blue pigment dissolves and can be filtered clear, if a little acid is added to dissolve the $CaCO_3$. A slight amount of alkali changes the color to red orange, but the blue does not return in acid.

A blue water solution decomposes on boiling to compounds of a dirty straw color. A blue water solution shaken with ether, chloroform, or benzol is turned red and none of the red is absorbed. If the ether or chloroform is evaporated, the blue color returns. An alcoholic solution, however, remains red on evaporation to dryness.

Both red and blue color varieties gradually bleach in sunlight.

Report upon Color of Fishes of the Tortugas Reefs, by W. H. Longley.

The study of the reef-fishes of Tortugas in the season of 1914 has led to the recognition of a number of interesting facts. The first concerns a small group of five species, belonging to three families, and including all the truly red fishes of which I have obtained full-grown specimens in the shallow water of the inner reefs. These are the squirrel-fishes, *Holocentrus siccifer*, *ascensionis*, and *tortugæ*, together with *Amia sellicauda* and *Priacanthus cruentatus*. Their conspicuousness under certain conditions is unquestionable.

These red fishes have one striking habit in common. All lurk in sheltered crannies of the coral heads during the day and emerge from them at night. Twice during a month of close observation, I saw a specimen of *H. siccifer* beyond the shelter of the reef for a short period during the day, but never saw any individual of any other of the five species so exposed. Not infrequently, however, the snout, tail, or large eye of *Priacanthus* may be seen through a crevice, or even the whole body of a squirrel-fish in the depths of one of the deeper narrow clefts in the coral. But I have taken six individuals of four species with a single charge of dynamite and rarely failed to obtain some when blasting among the heads. Again, one may see, after dark, in the vicinity of the same heads which seem uninhabited by them during the day, more red fishes than there are of all other species combined. Finally, the unusually large eyes of these fishes suggest that they are accustomed to living in light of low intensity.

In view of the facts noted, I consider it highly probable that the red pigment of these fishes has the same biological significance as that of the many red animals living at great depths where the light-waves have been very largely absorbed by the water through which they have passed, and that in neither case does it minister to the conspicuousness, but rather to the inconspicuousness, of the animal displaying it.

A second series of facts concerns the modification of color pattern within the limits of a family. Both in the snappers (Lutianidæ) and grunts (Hæmulidæ) there are generalized patterns which, by the reduction or extension

duplication, or fusion of elements, produce the markings of the different genera, which in some cases are superficially quite unlike. In determining the course of evolution of the color pattern of adults, the study of immature specimens is of the greatest importance.

In studying the color phases of some of the fishes whose power of color change is greatest, it becomes very clear that the character of the *changing* patterns in related species may be fixed with a degree of definiteness quite as great as that which prevails when the distribution of pigments is more nearly permanent. *Scarus punctulatus* and *croicensis* have a mottled phase which, considered in either alone, would seem to be the acme of irregularity. And yet different though the pigments are, the color pattern is essentially the same in the two cases.

From the facts noted, a high degree of conservatism in color pattern may be inferred, indicating that, if the present colors and patterns exist by virtue of their selective value, their character is considerably influenced by the antecedent pigments and patterns whose variations were the raw material upon which selection operated.

Additional facts concerning the colors and behavior of the reef fishes have been noted which may not at present be concisely summarized. For example, the labroid fishes *Chloricthys bifasciatus* and *Iridio bivittatus*, if kept in a tank with loose coral sand upon the bottom, will bury themselves in it at dusk and remain concealed until daybreak. The regularity with which the reaction occurs and the close phylogenetic relation of the two species support the belief that it is a natural response to the stimulation of light. The fish will give the reaction at any time during the day if light be excluded from their tank. They are not visible upon the reef after dark, but I have not seen one conceal itself in the sand there. The act of concealment requires only a fraction of a second for its completion and therefore may commonly escape observation, though occurring regularly. Again, *Chloricthys bifasciatus*, *nitidus*, and *nitidissimus* are apparently a single species. The differences between *nitidus* and *nitidissimus* are transitory, the characteristic color of one at times replacing that of the other almost instantaneously. The differences between *nitidus* and *bifasciatus* are those existing between immature and mature forms. Every appreciable degree of difference between the undifferentiated pattern of *nitidus* and the highly specialized pattern of *bifasciatus* may be seen in a single school of the fishes, together with the phase which was described as *nitidissimus*.

Researches at Murray Island, by F. A. Potts.

The Rhizocephalan Cirriped Thylacoplethus Coutière.

This form was described by its discoverer from three infected specimens of *Alpheus* collected in the neighborhood of Torres Straits, but as the material was neither fresh nor well preserved, he was not able to give a sufficiently full or correct account of the parasite.

At Murray Island *Thylacoplethus* was found fairly commonly on a species of *Alpheus* commensal with *Comatula*. Infected hosts show a large number of small pink sacs attached to the thoracic legs and the abdominal swimmerets. These sacs consist simply of a mass of reproductive cells or embryos surrounded by a thin body-wall, and all the sacs are connected by a common root system running directly above the ventral body-wall and sending off delicate branches into all the appendages. The fine, colorless roots are only to be detected in living or specially preserved animals, and it is on this account that Coutière considered a root system to be absent.

Thylacoplethus differs from other known Rhizocephala in that it does not prevent the molting of the host. When this takes place the external sacs are detached from the root system, but this will probably not prevent the larvæ from pursuing their normal development. The root system buds off a new set of external sacs, so that the germ-cells are actually formed in the roots. These cells grow considerably in size, and form a number of yolk globules, but the fully formed egg is small for a rhizocephalan. The maturation processes were not observed, but neither testis nor any spermatozoan-like bodies were found, and there can be no doubt that reproduction is parthenogenetic. The egg undergoes complete segmentation; the nauplius stage is passed through within the egg membrane and eventually the larva hatches in the *Cypris* stage. In the absence of a definite aperture to the exterior, it must be liberated either by the molting of the host or the tearing of the external membrane.

Thylacoplethus thus occupies a unique position among the Rhizocephala on account of its simplicity of structure, a simplicity which is doubtless the result of degeneration. The mantle cavity, nervous ganglion, testis, and reproductive ducts which characterize the higher Rhizocephala are all lost here. On the other hand, the development of a large number of external sacs from a single root system is a new feature. In the complete segmentation of the egg, *Thylacoplethus* differs from all other Crustacea.

Commensal Animals Associated with Comatula.

With practically every individual of *Comatula parvicirra*, a pair of alpheids, male and female, is found, generally lying side by side on the disk of the crinoid. The animals can move about quite freely, but are guarded against detachment in the one species by the recurved double claws on the thoracic legs and in the other by a great modification of the smaller chela, which is usually fixed firmly in the flesh of the disk. The coloration of the alpheids varies greatly and corresponds roughly with that of the host, which is also very variable. The same variations occur in both species.

A number of other forms are definitely associated with *Comatula* as commensals. These include a *Munida*, two kinds of shrimps, an amphipod, and an isopod among Crustacea; various myzostomids and a polynoid polychæte; and one or two species of ophiuroids. In most of these cases the coloration shows some relation to that of the host.

The Biology of the Gall-Forming Crab, Hapalocarcinus.

Hapalocarcinus was abundant at Murray Island in galls on the coral *Pocillopora*. Previously, the female only was known and the reproductive habits were consequently a matter of conjecture only. It appears, however, that the *female* alone forms galls, settling down to a sedentary existence when still very small and immature. Only in the fully formed galls are the big, mature females found with their swollen abdomen (occupied by the large ovary) and well-developed swimmerets. The mature *male* probably never attains a size as great as even the smallest gall-inhabiting female, but is easily recognizable by the copulatory stylets and large testes. It is probably free-living, visiting the female when she becomes mature, entering the gall through one of the respiratory apertures. The only male found was obtained in a gall with a recently-molted female. It is perhaps misleading to apply the term "gall" to the structures inhabited by *Hapalocarcinus*. The broadening of the naturally slender branches of the coral to form a protection for the crab is due to the respiratory currents of the crab, which merely controls the direc-

tion of growth of the polyps and does not cause an abnormal growth of tissue by mechanical or chemical stimuli, such as occurs in the plant galls inhabited by insects.

A Note on the Hermit Crab, Pagurus deformis.

It has long been known that the male of this species possessed, besides the normal pair of reproductive apertures on the last pair of walking legs, an additional pair in the position usually occupied by the female apertures. It was regarded as important to see whether other indications of hermaphroditism were to be found in the male, especially in view of the secondary hermaphroditism which occurs in some male hermit crabs which are infected by rhizocephalan parasites.

The species was not abundant at Murray Island, but the individuals collected showed plainly that the males and females are easily distinguishable from one another and that true hermaphroditism does not occur. Though the male invariably possessed supplementary apertures, the corresponding ducts and glands have not been observed and the swimmerets are never of the female type. Nor does the testis show any signs of hermaphroditism, though I have yet to cut sections of these.

No male characters are developed in the female and it is evident that we have here a curious case of the inheritance by one sex of a single secondary sexual character belonging to the other, such as occurs in the female reindeer, which has horns like the male.

Report upon the Behavior of the Dimorphic Spermatozoa of Strombus, by Edwin E. Reinke.

The investigation carried on this year at Tortugas is a direct continuation of the work which was accomplished and reported on last year. Although no definite general conclusions have been reached as yet, it would be well to make a statement of the problem as it presents itself to the writer, and to describe the methods used in attacking it, together with a brief outline of the results obtained so far.

The writer has shown[1] that, in their development, the atypical or apyrene spermatozoa lose their nuclei and every trace of chromatin disappears from the cell. Hand in hand with the loss of chromatin proceeds the formation of secreted bodies which eventually fill the entire cell. Two undulating membranes, which are developed on both sides of the cell-body, provide the apyrene spermatozoon with a high degree of motility. The development of the typical or eupyrene spermatozoon corresponds in its essentials to that which has been described for the eupyrene spermatozoon of other Prosobranchs.[2]

The view has been expressed by the writer that the apyrene spermatozoa of *Strombus* are accessory cells of the testis and are not spermatozoa in the true (physiological) sense of the word. An examination of a number of females which had undergone copulation showed several things very clearly. In the first place, the apyrene spermatozoa found in recent ejaculates are in the same condition as when found in the sperm-ducts; that is, the undulating membranes and the secreted bodies are intact and the cells become activated when mixed with sea-water. Second, a sharp separation of the two kinds of sperma-

[1]Papers from the Tortugas Laboratory of the Carnegie Institution of Washington, vol. 6, 1914.
[2]See Meves, Fr. Arch. für Mikr. Anat. Bd. 61, 1903. Also: Kuschakewitsch, S. Arch. für Zellforsch., Bd. 10, 1913.

tozoa takes place; this is probably accomplished by the clumping of the apyrene spermatozoa and the very active movements of the eupyrene away from the former. Third, the eupyrene spermatozoa are stored and nourished in a specialized portion of the oviduct, the seminal receptacle. Fourth, the apyrene spermatozoa never reach the seminal receptacle, but instead they pass into a large, blind sack, the bursa seminalis, where they may be found, together with eupyrene spermatozoa, in all stages of katabolism. Eventually the entire mass becomes encapsulated by a secretion from the walls of the sack and is thrown off. It is probable that during copulation the ejaculate is placed in the bursa seminalis, although in several instances when the latter was full, a recent ejaculate was found lying free in the mantle cavity.

While these facts give no positive indication of the function of the apyrene spermatozoa, they eliminate the possibility of a direct participation by them in fertilization. It is believed, however, that they may play an accessory role in fertilization or may aid in the final disposition of the eupyrene spermatozoa. The most fruitful way of attacking this question is by an experimental investigation of the behavior of the two kinds of spermatozoa. That much information concerning the phenomenon of fertilization can be gained from this kind of research has been amply shown by the work of Lillie[1] and Loeb.[2] In addition to that broad field of investigation, the problem here is unique in that, in the case of the apyrene spermatozoa, we are dealing with non-nucleated cells, and any information which may be gathered concerning their behavior will doubtless have an important bearing upon cellular structure and physiology.

A set of preliminary experiments clearly established three of four general facts which must be reckoned with. The first of these is that the two kinds of spermatozoa of *Strombus* withstand a far greater range of changing conditions than do the spermatozoa of *Nereis* or *Arbacia*. Thus, for instance, when placed in a mixture of equal parts of normal sea-water and sea-water charged with CO_2 from a "sparklet" bottle, their behavior is practically the same as in normal sea-water, except that the reactions take place more slowly. When placed in undiluted sea-water charged with CO_2, which has been allowed to stand for 8 to 10 minutes until the bubbles cease to arise, they still retain a slow degree of activity. The apyrene spermatozoa show remarkable powers of recuperation after exposure to solutions hypotonic to sea-water.

When placed in 90 per cent sea-water, that is, in 90 parts of sea-water mixed with 10 volumes of distilled water, the apyrene spermatozoa act normally after a slight stimulation. When the percentage of sea-water is further reduced, water is absorbed by the cells, and these become greatly swollen, distorted, and immobile. When, by evaporation, the concentration of the salts in such a culture is increased to within 10 per cent of that of normal sea-water, there ensues a loss of water from the cells and the apyrene spermatozoa resume their normal appearance and activity.

By a series of experiments it was found that the apyrene spermatozoa would recover even after being subjected to 60 per cent sea-water. At greater dilutions than that, however, they were usually permanently impaired. It was also found that the apyrene spermatozoa would withstand a 10 per cent increase, by evaporation, in the concentration of sea-water, but the limits from which they would recover in this direction have not been determined. The eupyrene spermatozoa also recover after exposure to certain degrees of dilution and concentration of sea-water, but their range is not so great as that of the apyrene.

[1]Journ. of Exp. Zool., vol. 14, 1913; also, vol. 16, 1914. [2]*Ibid.*, vol. 17, 1914.

By another set of experiments it was shown that both kinds of spermatozoa withstand a relatively great increase in alkalinity of the medium in which they are placed. In these experiments was used a 0.62 *m* NaCl solution, neutral to phenolphtalein; the alkalinity of the solution was increased by the addition of carefully measured quantities of a standardized N/2 solution of NaOH In a solution of N/600 NaOH in 0.62 *m* NaCl, the movements of the eupyrene spermatozoa were practically normal, while activity among the apyrene was increased. When the NaOH content was increased, making a N/400 solution, there occurred a complete paralysis of both kinds of spermatozoa.

In the course of a set of experiments, the object of which was to determine the normal reactions of the spermatozoa in pure sea-water, two general facts of importance were discovered. In the first place, the reactions of the spermatozoa, under the conditions of the experiment, take place very much more slowly than do those of the spermatozoa of *Nereis* or *Arbacia*, and very often with less definitive results. In the second place, variations in the rapidity of the reactions and in their duration and intensity were caused by at least four factors: (1) the condition of the animal; (2) the portion of the sperm-duct from which the sperm-fluid was drawn; (3) the concentration of the mixture of spermatozoa and sea-water; and (4) the condition of the sea-water itself. To the first of these factors was due a considerable amount of trouble and lack of uniformity in results during the first half of the season, when the attention of the writer was confined entirely to *S. gigas* (*costatus?*). For some reason, which is not yet fully understood, there has been for the last two seasons a steady decrease in the number of the mature males and females of this species, the so-called conch. Considerable difficulty was experienced in collecting a sufficient number of males and those which were obtained were subnormal; in these cases the reactions of their spermatozoa showed many puzzling disparities. Before the end of the season, however, *S. bituberculatus* was found in great numbers, and not only were the mature males more healthy, but they were more economical on account of their smaller size, in that a fresh specimen could be used for each experiment. Again, the use of *S. bituberculatus* eliminated the second factor, since the sperm-ducts of that species will not supply ordinarily more sperm-fluid than enough for one experiment. In the case of *S. gigas*, however, the sperm-ducts are so large that they can be tapped successively at the distal, median, and proximal portions, and it is unquestionably true that the spermatozoa from these three regions showed differences in the rate and intensity of their reactions, those from the distal end being the more active.

The concentration of the mixture of sperm-fluid and sea-water has an important bearing upon the agglutination phenomenon. When the sperm suspension is too thin, agglutination (in Lillie's sense) of the eupyrene spermatozoa invariably fails to take place. In order to assure a maximum degree of activity and, at the same time, to keep the culture from being too dense for microscopical examination, a certain standard concentration was determined empirically. The suspension which was found best for these requirements was a mixture of a column of sperm-fluid, 7 mm. high, in the end of a pipette which was 1 mm. in diameter, with 20 c.c. of pure sea-water, or any other aqueous solution which was used. The variations which arose by the use of this method were not great enough to be of any consequence. This standard suspension was used in all subsequent experiments.

A considerable amount of variation in the results obtained in these experiments was unquestionably due to slight changes in the alkalinity and the carbon-dioxide content of the sea-water used. To obviate this difficulty only the purest obtainable filtered sea-water was used, and this was constantly

replaced and not allowed to stand. Eventually an artificial sea-water was used which is based upon F. W. Clarke's analysis of the sea-water at Tortugas, and is composed of the following elements: 100 c.c. of 0.6 *m* NaCl + 17 c.c. of 0.4 *m* $MgCl_2$ + 3.5 c.c. of 0.4 *m* $CaCl_2$ + 2.1 c.c. of 0.62 *m* KCL.[1] The behavior of the spermatozoa of *Strombus* in this medium corresponds very closely to that in pure filtered sea-water. It is proposed in the future to substitute this medium for the other, since it can be made up in a large quantity at one time, neutral to phenolpthalein, thus doing away with any changes in the composition of the medium. As mentioned above, in certain experiments, the object of which was to determine the effect of increased alkalinity on the behavior of the spermatozoa, a 0.62 *m* NaCl solution was used as a medium. The effect of neutral sodium chloride is to cause a primary stimulation of both kinds of spermatozoa, which is followed by a depression of their activity, shortening the duration of the reaction. Another important effect of sodium chloride will be mentioned below.

In a set of experiments, the object of which was to determine the behavior of both kinds of spermatozoa in pure normal sea-water under a raised cover, the following technique was finally adopted: The specimen was opened and the sperm-ducts were exposed; this region was washed with pure sea-water and then the ducts were ruptured, permitting a flow of sperm-fluid. The required amount of the latter necessary for a standard suspension, as given above, was drawn up into a chemically clean pipette and was discharged into 20 c.c. of the purest obtainable filtered sea-water contained in a chemically clean watch-glass. The thorough mixing of the suspension was completed by drawing up the contents of the watch-glass into the pipette and then discharging it, repeating the operation at least three times. A portion of the suspension was then transferred to a slide upon which were permanently sealed, by means of a thin layer of paraffin, two parallel glass supports for the cover, both of them slightly longer than the width of the cover itself and about 1 mm. thick. A cover-glass was then placed upon the culture and a sufficient amount of the suspension was added or withdrawn to bring it flush with the free edges of the cover. Observations, together with data upon the time and the room temperature, were carefully recorded. Loss by evaporation was made up by the addition, as required, of small quantities of distilled water tested free from chlorides and sulphates. This treatment had no appreciable effect upon the results of the experiment, owing to the behavior of both kinds of spermatozoa in hypotonic and hypertonic solutions and to the effect of surface tension in the culture, a phenomenon which will be described later. After the normal behavior of the spermatozoa had been satisfactorily determined, cultures such as just described were always used as controls in experiments in which the conditions were varied, as, for instance, when using a 0.62 *m* NaCl solution or CO_2 charged with sea-water instead of pure sea-water. The same technique was adhered to when artificial sea-water was used as the medium.

The following description of the behavior of both kinds of spermatozoa of *Strombus* in pure sea-water, in cultures of this kind, is based upon the observation of many experiments, the results of which were quite uniform. It must be remembered that this description only applies when the following conditions have been fulfilled: First, the animal must be fresh, the sperm-ducts full, and the sperm-fluid must be drawn only from the distal portion of the ducts; second, the concentration of the spermatozoa in sea-water must be

[1]See Mayer, A. G. Papers from the Tortugas Laboratory of the Carnegie Institution of Washington, vol. 6, 1914.

a close approximation to that which was described above as being the standard; third, the sea-water must be pure and freshly drawn and must be free from any excess of carbon dioxide or hydroxyl ions above that which is normally present, or, better still, an artificial sea-water, made up according to the formula given above, should be used; and fourth, the technique described should be followed in making the culture. Under these conditions, if the culture is observed immediately after being started, it will be seen that the eupyrene spermatozoa, which lie in tufts or bunches, are very slowly active, while the apyrene are totally inactive. Within 1 minute a great increase is noticeable in the activity of the eupyrene spermatozoa, and within 3 to 5 minutes they will have reached their maximum activity; if the tufts are still intact they will be seen swirling around and lashing the apyrene spermatozoa about. It very often happens, however, that even before maximum activity is reached the tufts are broken up and the spermatozoa begin to swarm about freely. When this occurs it will be noticed that the apyrene spermatozoa begin to become active, generally about 5 minutes after the culture was started. This activity does not imply much actual motility; it is usually confined to a beating of the undulating membranes. At this time, too, the effect of surface tension becomes visible to the naked eye, in that two dense streaks of the eupyrene spermatozoa are formed parallel to the free edges of the culture and about 2 mm. distant from them. That the formation of these streaks or bars is due to the effect of surface tension is shown by the fact that the free eupyrene spermatozoa can be seen under the microscope to be actually drawn away from the free edges of the culture, no matter in which direction they may be swimming.

It will be noticed that there has been no aggregation of the spermatozoa in the sense in which Lillie uses the word. In a 0.62 *m* NaCl solution, however, aggregations visible to the naked eye can be seen 2 minutes after the culture is started. The aggregations become very dense and definitive, but within 8 or 9 minutes they begin to break up, and free spermatozoa are given off in increasing numbers. This phenomenon is quite different from that of the agglutination of the eupyrene spermatozoa; it is never a permanent condition and apparently takes place only while the tufts are still intact. Another effect of sodium chloride is that within one-half of a minute activity is usually apparent among the apyrene spermatozoa, and these continue active after the eupyrene spermatozoa have ceased to move. In these sodium chloride cultures all activity ceases within 2 hours, sometimes within a shorter period than that.

Within the next 30 to 40 minutes the effect of surface tension becomes more and more evident in that the bars mentioned above recede farther and farther from the free edges of the culture until they meet and form a dense mass across the middle of the culture. If, during this time, the culture is examined under the microscope, it will be seen that the apyrene spermatozoa, and these lie at the lowest focus, have gradually become less active, except at the free edges. In the middle region of the culture, above the apyrene spermatozoa, lies the dense mass of active eupyrene spermatozoa. When this configuration has been reached a number of agglutinations are formed in the mass of eupyrene spermatozoa, and these continue to increase in size. Soon after the agglutinations are formed it will be seen that the apyrene spermatozoa lying immediately beneath them become active, and this time the activity is continued.

About an hour after the culture is started, in its middle region and at high focus, there is a dense mass of still very active eupyrene spermatozoa; beneath these are still denser agglutinated masses, between which may be seen active

eupyrene spermatozoa in great numbers, while around the fringes of the agglutinations are active apyrene spermatozoa. Although the latter often seem to be heaped up about an agglutinated mass and appear to be actively pressing against it, this is not thought to be a chemotropism, since sometimes an apyrene spermatozoon is seen moving directly away from the vicinity of such a mass. On the other hand, it is believed that the massing of the apyrene spermatozoa is due to the fact that they have been activated and to the peculiar manner in which they move. It has been repeatedly observed that an apyrene spermatozoon, once having started in a certain direction, always maintains it, unless one of the undulating membranes is stronger than the other, when it will tend to travel in a circle. This last, however, is a condition which only occasionally obtains. When an apyrene spermatozoon meets an object it does not avoid it in the least, but merely pushes against it all the harder. If it overcomes the obstacle it continues its way in the same direction as before, but if it fails to get by it stays there, continually pushing against the object.

The conditions which obtain in a culture after the first hour are maintained with but little change for several hours, there being a slight and gradual increase in the size and number of agglutinations formed, but always there are great numbers of active eupyrene spermatozoa above these masses. Finally, however, the activity of the free eupyrene and of the apyrene spermatozoa gradually slows down and then ceases, the duration of the culture depending entirely upon the care with which it is maintained. In hanging-drop cultures which were sealed with vaseline this condition of balance has been maintained for as long as 72 hours, in fact until bacterial action put an end to it.[1]

The question naturally arises, does the activity of the apyrene spermatozoa tend to prevent further agglutination of the eupyrene spermatozoa? The writer is not in a position to answer this question directly, but one or two conclusions may be pointed out which seem to be fully justified. The agglutination of the eupyrene spermatozoa is undoubtedly caused by a substance given off by themselves as a result of their activities. The formation of the two dense bars parallel to the two free edges and then their meeting to form a dense area of eupyrene spermatozoa across the middle of the culture shows that this substance raises the surface tension. That this substance is alkaline in its nature is indicated by certain experiments in which a drop of a N/100 NaOH solution was introduced beneath the cover by means of a capillary pipette at a time when the agglutinations were beginning to form. This had the effect of causing an intense stimulation of short duration of the eupyrene spermatozoa in the immediate neighborhood of the drop; this was followed by their agglutination. The effect upon the apyrene spermatozoa was to increase their activity. From the constant occurrence of the resumption of activity by the apyrene spermatozoa around agglutinations of eupyrene spermatozoa, it seems evident that the substance which causes the latter stimulates the apyrene spermatozoa to activity.

There is considerable evidence which indicates that the two kinds of spermatozoa of *Strombus* together show the properties of facultative anaerobes, and also, as far as it has been tested, that the things which stimulate the one kind of spermatozoon inhibits the activity of the other, and *vice versa*. It has been stated already that in cultures started in CO_2-charged sea-water, from which the bubbles have ceased to arise, the activity of the eupyrene spermatozoa is greatly inhibited, while the apyrene spermatozoa are altogether stopped, except at the free edges of the culture, where they come into contact

[1]Carnegie Institution of Washington Year Book No. 12, p. 178, 1913.

with oxygen. In cultures in which there was less carbon dioxide the inhibitory effect on both kinds of spermatozoa was less. In cultures made in pure sea-water and into which a bubble of pure carbon dioxide was introduced, the increased activity of the eupyrene spermatozoa around the bubble indicated very clearly that there is a certain carbon-dioxide tension at which they reach maximum activity. The reaction of the apyrene spermatozoa was less definite, although there was not the slightest evidence that they were stimulated. When a bubble of pure oxygen, however, was introduced, the eupyrene spermatozoa were slowed down to a great extent. In this case the apyrene spermatozoa were stimulated. The end reactions of the two kinds of spermatozoa to bubbles of carbon dioxide and of oxygen presented configurations of ring formation, both of which lend themselves to the same interpretation when the opposite effect of the gases upon the two kinds of spermatozoa is borne in mind. The writer, however, is not willing to commit himself in this regard until the effects of other gases, such as hydrogen and nitrogen, and of substances which raise and lower surface tension have been studied.

That the combined activity of both kinds of spermatozoa results in the production of a relatively great amount of carbon dioxide was demonstrated by Dr. S. Tashiro, of the University of Chicago, by means of his biometer.

Upon CO_2 Production in Tropical and in Temperate Marine Animals, and upon CO_2 in Sea-water, by Dr. Shiro Tashiro.

The results obtained at the Marine Biological Laboratory at Tortugas during June 20–July 30 are given under the following headings:

I. Metabolism in ganglionated cord of the heart of the king crab (*Limulus*) at Tortugas.
II. Temperature coefficient of the metabolism in the nerve fibers.
III. Further evidence for the increased CO_2 production in nerve fiber on stimulation.
IV. Tissue metabolism in the medusa *Cassiopea*.
V. Is there any free CO_2 in sea-water?

I. Metabolism in the Ganglionated Cord of the King Crab (Limulus polyphemus) at Tortugas.

Mayer's discovery that the death temperatures of the different species of reef corals vary considerably according to the localities in which the animals occur is a matter of considerable importance from both a physiological and an ecological point of view. In general, he confirms Harvey's statement that tropical marine animals normally live at temperatures much nearer the high-temperature death-point than do northern forms. The highest temperatures at which the king crab, *Limulus*, at Tortugas can live is not very much higher than that of the northern forms, while its lower limit of activity is considerably higher than that of the northern forms. In order to explain the mechanism of this physiological difference, I made a series of studies of the metabolic activities of the animals of both regions at various temperatures. Since I have (with Mr. H. S. Adams) measured the CO_2 production by the ganlionated nerve cord of the *Limulus* heart at Woods Hole, a similar investigation was conducted on the tissue of the same form at Tortugas.

By using the biometer, which measures quantities of CO_2 as small as 0.0000001 gram, the rate of CO_2 production in the ganglionated cord of the *Limulus*, obtained at the Marquesas Keys, near Tortugas, was determined.

From the quantitative determinations, the following conclusions have been reached:

1. The rate of CO_2 production in the ganglia of the Tortugas *Limulus* at 27° C. is slower than that of the northern forms at 23° C.
2. In both regions, a male is usually smaller in size than a female. It was previously noted in the northern forms that the rate of CO_2 production in the ganglia of the male was considerably higher than that in the female. A similar difference was discovered to exist in the ganglia of the two sexes at Tortugas. Whether this difference was due to the differences of age, sex, or mere size of cord was not determined.
3. This difference in metabolic activity of the two sexes is, however, only true at normal temperatures. At 33° the ganglia from both sexes give about the same amounts of CO_2 for a gram of the tissue. In other words, the temperature coefficient of CO_2 production in the ganglia of the female heart is lower than that of the male from 27° to 33° C.
4. A similar difference was observed in the claw nerve of the same animal at Tortugas.
5. By comparing the observations made at Woods Hole with those made at Tortugas, I came to the following conclusions: The tropical animal can live near the death-point, not because it can maintain a higher rate of metabolism, but rather because of differences in the protoplasm which produce a relatively low rate of metabolism in high temperatures. This conclusion is further supported by the behavior of the tropical *Limulus*, which, to all appearances, does not exhibit any greater muscular activity than does the northern form, although if it had a greater rate of metabolism in the tropics greater muscular activity might be expected. This conclusion is merely a suggestion, however, and should be further tested upon other forms as well as upon other tissues before we draw a general conclusion.
6. Although there seems to exist a certain relation between heat paralysis, death temperature, and general tissue metabolism, we can not yet say what determines death temperature. It would be very interesting to measure the metabolic activities of the ganglia in the neighborhood of the higher and lower death-points in both regions, an experiment which was not practicable with the biometer without some modifications.

II. Temperature Coefficient of Metabolism in the Nerve Fiber.

In recent years it has been pointed out by many that magnitude and variation of the temperature coefficient of physiological activities does not necessarily tell us what kinds of reactions are involved. This argument has been against the view that the relatively high temperature coefficient of the velocity of nerve impulse suggests that the nerve impulse is of a chemical nature.

Since it has been demonstrated that the resting nerve fiber gives off CO_2, and, on stimulation, its CO_2 production is increased, the direct determination of a chemical change in the nerve fiber under various temperatures was very desirable.

Although the present form of the biometer is such that it can not be used satisfactorily for large variations at high temperatures, it could easily be used to determine the amounts of CO_2 produced at various temperatures between 27° and 33°, which are the natural temperature changes at Tortugas.

From various quantitative determinations, it was shown that the amount of CO_2 produced by the claw nerve of *Limulus* at 27° without stimulation is

nearly doubled at 33°. The claw nerve of the male *Limulus*, however, does not show so great a range as that of the female and thus the effects of temperature on the nerve fibers of different sexes are exactly similar to those on the ganglia.

The temperature coefficient of the nerve impulse is about 2 to 3 for each 10-degree interval, decreasing gradually as the temperature rises, but in no case, if I am not mistaken, does the coefficient go above 2 at as high a temperature as 27°. Even in *Cassiopea*, which lives at a temperature of about 30°, the temperature coefficient for nerve impulse is not quite 2 at temperatures ranging from 27° to 33°. The wide difference between the coefficients of the velocity of nerve impulse and the resting nerve metabolism seems to indicate, at first sight, that nerve impulse is of a nature different from that of resting metabolism in the nerve fiber. However, since the accumulation of CO_2 is known to be very detrimental to the conduction of the nerve impulse, the gradual increase of the temperature coefficient of the velocity of the nerve impulse as temperature rises may be due to the accumulation of the metabolic by-products produced by steady increase of tissue metabolism as the temperature is raised. This may explain why many curves of temperature coefficient of the nerve impulse (Harvey) and regenerating activity (Goldfarb) and many other physiological phenomena appear to be "enzymic curves" rather than van't Hoff's curve of chemical reaction, and the possibility of the operation of other simple physical factors, such as Snyder points out in case of changes of viscosity in the physiological fluid, may be considered.

However this may be, the fact seems to indicate that the fundamental conditions for the conduction of nerve impulse are determined by metabolic conditions in the nerve before stimulation. It is important, therefore, to determine the temperature coefficient of the increase of CO_2 production on stimulation.

III. Further Evidence for the Increased CO_2 Production in Nerve Fiber during Stimulation, with Particular Reference to High Temperatures.

It has been demonstrated that when a nerve impulse passes through the nerve fiber, CO_2 production is more than doubled. Since the temperature coefficient of the velocity of nerve impulse is not so great at higher tempertures as at lower, it is of interest to estimate the increased production of CO_2 in the nerve fibers of tropical animals during stimulation.

The determination made on the claw nerve of *Limulus* at Tortugas at 32° to 33° shows that the production of CO_2 on stimulation is about doubled, which is less than that in other nerves determined at Woods Hole. Whether this rather slight increase of CO_2 on stimulation in tropical nerve is characteristic of the nerves of all animals at high temperatures can not be determined until similar investigations are made upon the nerves of other animals at Tortugas as well as upon the nerves of the same species at Woods Hole. It is quite possible that the comparatively low rate of nerve impulse in the claw nerve of *Limulus* may be directly connected with less CO_2 increase on stimulation than is the case in other nerves which have a higher velocity of nerve impulse.

IV. Tissue Metabolism in Cassiopea xamachana.

Since *Cassiopea* has been a subject of various important biological investigations at Tortugas, it is of interest to test, with the biometer, the metabolic activities of the animal under various conditions, in order to see how far the metabolic factors are responsible for certain known physiological phenomena.

From the quantitative determinations of CO_2 production under various conditions, the following conclusions are reached:

1. An annular piece cut from the peripheral region of the body produces an exceedingly small amount of CO_2. This low production of CO_2 does not, however, indicate a low rate of metabolism in *Cassiopea*, for, if the estimation is made in darkness, CO_2 production is more than doubled. This result confirms the fact observed by Mayer, and familiar to all who work with this form at Tortugas, namely, that commensal plant cells, within the gelatinous substance of the disk of the animal, synthesize the CO_2 in light.

2. CO_2 production in *Cassiopea*, measured even in darkness, is much less than in any other tissues I have as yet studied, with the probable exception of unfertilized eggs of *Fundulus heteroclitus*. This, however, is due to the large proportion of comparatively inactive gelatinous substance in the exumbrella region, which gives less than one-fourth the CO_2 given off by the subumbrella regions. Mayer has shown that the subumbrella region is a most active portion, physiologically, and is exceedingly sensitive to CO_2, while the animal can go on functioning even if the exumbrella region is killed by $HgCl_2$. My results seem to indicate that the more metabolically active the tissue the more susceptible it is to stimuli.

3. Mayer found that rate of nerve conduction in the subumbrella region increases about 5 per cent in sea-water diluted with distilled water (9 : 1), while it decreases to about 50 per cent in 50 per cent sea-water. By using 0.9 molecular dextrose instead of distilled water, he obtained practically the same effects. By these experiments he demonstrated that the decrease in the rate of nerve impulse in sea-water diluted with distilled water is not due to the decrease in osmotic pressure, but to the corresponding change in the concentration of the electrolytes. I have previously endeavored to show that changes in physiological activities produced by change in concentration of the electrolytes is very closely associated with changes in tissue metabolism. The change in the rate of nerve impulse in *Cassiopea*, therefore, may be directly correlated with the change in the metabolic activity which might take place in the nerve tissue. My experiments show that a corresponding change occurs in the CO_2 production in the subumbrella region if the animals are treated as was done by Mayer. The decrease of CO_2 production in a diluted sea-water is more decidedly shown if we take the regenerating ectoderm before the muscle regenerates. These results strongly suggest that the decrease of metabolism in the nerve tissue may be the primary cause of the decline of rate of nerve impulse in *Cassiopea* in dilute sea-water.

4. At the request of Dr. Cary, the following observations were made:

(*a*) A semi-annulus cut from the peripheral portion of one half of the disk of *Cassiopea* without sense-organs gives off less CO_2 than one cut from the corresponding half with sense-organs intact. Neither piece contracted during the experiments.

(*b*) A semi-annulus cut from the peripheral portion of a half disk of *Cassiopea* with sense-organs intact gives more CO_2 than one cut from the corresponding half of the animal without sense-organs, but which had been stimulated electrically so as to produce contractions before the time of the experiment, although both halves were quiescent during the experiment.

5. Does sea-water contain free CO_2?

This question was considered upon a request of Doctors Mayer and Vaughan. Working upon samples of Tortugas sea-water collected by Dr. Vaughan, Mr. Dole came to the following conclusion: "The quantities of acid required to neutralize the cold sea-water in presence of phenolphthalein proves conclusively that *free* carbon dioxide, in the ordinary acceptance of the term in America, is not present." I have undertaken to conduct a similar investi-

gation with the biometer, this being a more delicate method, as it enables us to detect a quantity of CO_2 as small as 0.0000001 gram. The following is a merely preliminary report upon the results thus far obtained, the final conclusion being reserved for a later report.

1. Enormous quantities of CO_2 can be obtained from the cold sea-water without any mechanical disturbance. The quantity of CO_2 obtainable from sea-water under this condition is more than 50 times that contained in the same volume of natural air, which may be assumed to contain 3 parts of CO_2 in 10,000 by volume.

2. Since many bicarbonate solutions give CO_2 with equal ease under similar conditions, one can not say whether the CO_2 obtained from the sea-water is entirely due to decomposition of a bicarbonate or to the setting free of gas which existed as CO_2 in the sea-water itself, for the amount of CO_2 given off by the sea-water is so large that it is impossible to take an amount of sea-water small enough to contain the minimum amount of detectable CO_2, namely, 0.0000001 gram. On this account, the total CO_2 obtainable from a known amount of sea-water could not be determined.

3. In an attempt to settle this problem, the following lines of investigation are now in progress:

(*a*) One must devise an apparatus which will enable one to dilute CO_2 obtained from a small amount of sea-water.

(*b*) By calculating the maximum amounts of CO_2 obtainable by the same concentration of the carbonate and bicarbonate as that of the sea-water.

(*c*) By determining total carbonate in sea-water before and after aeration and the amount of CO_2 driven off by aeration, the method I have been using for determining CO_2 production in sea-water. It is obvious that if the total carbonate as CO_2 before aeration is equal to that of CO_2 driven off by aeration plus the total carbonate as CO_2 present in the sea-water after aeration, we may calculate how much CO_2 is due to the decomposition of bicarbonate. The fact that the sea-water gives off free CO_2 by aeration suggests from an equilibrium point of view that there must be some *free* CO_2 present in the sea-water, although it may be small in amount.

4. Sea-water seems to lose CO_2 on standing in contact with pure natural air containing the normal amount of CO_2, provided no bacterial decomposition takes place.

5. Judging from the preliminary experiments cited above, there is a possibility of *free* CO_2 being present in sea-water, but the evidence is not yet conclusive.

Researches upon Annelids at Tortugas, by A. L. Treadwell.

My work at the Tortugas Laboratory in the season of 1914 was a continuation of a systematic study begun in 1910, on the polychætous annelids of the family Leodicidæ (Eunicidæ). In this work I was again able to secure the efficient assistance of Mr. S. C. Ball as artist. We now have water-color paintings of the living animals of 20 species belonging to this family, with drawings of anatomical details amounting in all to 210 figures. It is my intention to continue this work to include a study of all members of the family which occur in West Indian waters.

Owing to the absence of mud flats, burrowing annelids do not occur in the Tortugas region, the only exceptions being a few forms, as sabellids and a few arenicolids, burrowing in the mud at the bottom of the moat at Fort Jefferson. The great majority live either in crevices in the coral rock or in tubes attached to the under side of stones, shells, or (at Fort Jefferson) attached to bricks of the moat wall. Wherever a coral rock has been perforated by boring sponges and mollusks, or wherever a crevice has been formed

by any disintegrating agency, annelids occur. The large loggerhead sponges contain many Syllidæ, and one leodicid (*Leodice conglomerans*) occurs only in these sponges, living inside a parchment tube of its own construction, which branches to follow the cloacal system of the sponge. In a few species the cavity occupied by the annelid passes through the solid rock in such a fashion as to indicate that it must have been excavated by the animal itself.

Certain of the serpulids and sabellids occupy tubes which open at the surface of the living coral rock, but in this case it is quite evident that the tube of the serpulid has begun its growth at the same time as that of the coral, and while the growth has been about equally rapid in the two animals, the tube has gradually been inclosed by the coral. Floating seaweed rarely carries any annelids except, occasionally, a few small nereids, and *Hermodice carunculata* is occasionally brought to the islands on floating logs. Probably the Leodicidæ is the largest in number of individuals of any annelid family represented here, with the Sabellidæ and Serpulidæ next. Nereidæ are comparatively rare, occurring in the coral rock in about equal abundance with representatives of the Capitellidæ, Cirratulidæ, Terebellidæ, and Syllidæ.

Unless there may be more than one breeding season in the year, and evidence on this point is as yet lacking, most of the annelids breed rather late in the season. *Leodice fucata*, the Atlantic "palolo," swarms in coincidence with the last quarter of the June-July moon, but there is no evidence of a similar habit in any other leodicid, and specimens of most of the species I have studied have been found still carrying large quantities of unripe eggs late in July. Specimens of *Onuphis* (*Paranorthia?*) brought from the Marquesas spawned in a live-car between July 12 and 15. In 1909 the only ripe annelid eggs I could find prior to July 15 were those of *Pomatostegus stellatus* and *Spirabranchus tricornis*. A small heteronereid was found swarming on July 12, and another *Nereis*, rather common at Fort Jefferson, was found with unripe eggs on July 24. Apparently the greater number of annelids in this locality breed later than August 1.

The swarming of the Atlantic "palolo," *Leodice fucata*, occurred on the morning of July 11, the last quarter of the moon falling on the 14th.[1] This swarming of annelids in coincidence with certain phases of the moon, formerly supposed to be limited to the Pacific "palolo," *Leodice viridis*, is now, owing to the work of Mayer,[2] Izuka,[3] Hempelmann,[4] and Lillie and Just,[5] known to

[1]The following table gives the dates upon which the Atlantic palolo has been observed to swarm at Tortugas, and the dates of the quarters of the moon. The date of the principal swarm is shown in heavy type, while the dates upon which only a few worms were observed swarming are shown in ordinary type.—A. G. M.

Year.	Dates upon which the palolo swarmed.	Dates of moon's quarters.	Year.	Dates upon which the palolo swarmed.	Dates of moon's quarters.
1898	July **9**, 10.....	Last quarter, July 10.	1907	July **2**, **3**......	Last quarter, July 2.
1899	1, **2**......	Last quarter, June 29.	1908	**10**, 19....	First quarter, July 6.
1900	**19**........	Last quarter, July 18.			Last quarter, July 19.
1902	24, **25**, 28.	Last quarter, July 27.	1909	6, 7......	Last quarter, July 10
1903	17........	Last quarter, July 17.	1910	June **29**, **30**....	Last quarter, June 29.
1905	9, 10, 21,	First quarter, July 9.	1911	July **16**, 17....	Last quarter, July 18.
	22, 23, 24	Last quarter, July 24.	1912	6, 7......	Last quarter, July 7.
1906	11, **12**, 13..	Last quarter, July 13.	1914	11........	Last quarter, July 14.

[2]Mayer, A. G. The annual breeding-swarm of the Atlantic palolo. Carnegie Inst. Wash. Pub. 102, 1908.

[3]Izuka, A. Observations on the Japanese palolo. Journal College of Science, Tokio, vol. XVII, 1903.

[4]Hempelmann, Fr. Zur Naturgeschichte von Nereis dumerilii. Zoologica, Bd. 25, Heft 62, 135 pp, 4 Taf., 14 figs. 1911.

[5]Lillie and Just. Biological Bulletin, vol. 24, No. 3, February 1913.

occur in *Nereis* and *Ceratocephale*, as well as in *Leodice*. In the last genus the process is more complicated than in the others, for only the sexual portion swarms, the non-sexual portion remaining behind. *Leodice fucata* lives in crevices in the rock, only the anterior end, carrying the gills, being protruded into the water. The posterior region becomes distended with sex products, and on the day of swarming is thrust out of the rock, twists with an anti-clockwise movement which breaks it away at the junction between the two parts of the body, and swims rapidly to the surface, where the sex products are discharged. Previous to the day of swarming, the sexual region does not normally come in contact with the open water, but if it accidentally does so, as happens when the rock is broken open, it usually starts twisting movements much like those of the normal swarming, but uncoordinated, so that the body is broken into pieces. Occasionally when taken from the burrow the sex region will break away and swim at the surface with a movement much like that of the normal swarming.

This sensitiveness to contact stimulus of the water, which is not shown by immature individuals, becomes more marked as the animals approach maturity, and is more evident in females than in males. It does not occur in the non-sexual portions left behind in the rocks, so must in some way be connected with the maturing sex products. Observations on *Podarke obscura*, made at Woods Hole in July 1913, showed that egg-laying in this annelid is preceded by the breaking down of the germinal vesicle, a process which can easily be observed through the translucent body-wall. Egg-laying occurs only in the early evening, and it is possible, by an examination of the entire animals, at least 3 hours earlier than the time of egg-laying, to determine which will lay that day. Evidently some part of the stimulus leading to egg-laying comes from the activity of the egg itself.

With a view to securing evidence on this point in the egg of *Leodice fucata*, I asked Dr. S. Tashiro to test with the biometer,[1] the amounts of CO_2 given off by these eggs in different stages of maturity. I wish here to express to Dr. Tashiro my appreciation of his courtesy in making the determinations. His results are as follows:

July 6, five days before swarming, a lot containing 300 eggs gave off CO_2 in an amount equivalent to 0.000,000,000,07 gram per egg per minute.

July 9, two individuals were selected, one of which was evidently more mature than the other. The relatively immature one, tested as above, gave 0.000,000,000,08, the more mature 0.000,000,000,13 gram per egg per minute.

July 11, eggs taken from the swarming female ends gave 0.000,000,000,18 gram per egg per minute. All observations were made on eggs taken directly from the body cavity, without any contact with sea-water.

These observations show that a definite increase in metabolism goes on in the egg as it approaches maturity, and that this must cooperate with the various external environmental agencies, previously regarded as the sole stimulus in determining the time of swarming. Similar internal stimuli determine the time of egg-laying in non-swarming annelids. In fact, it seems very probable that while swarming is more spectacular than more quiet egg-laying, essentially similar stimulations are responsible for initiating both processes.

Reef Corals of the Bahamas and of Southern Florida, by T. W. Vaughan.

BAHAMAS.

Most of the month of May 1914 was spent in company with Dr. Mayer in the Bahama Islands for the purpose of remeasuring the corals planted off Golding Cay in 1912 and those growing naturally which were measured at that time, making an additional inspection of the Andros barrier reef, collecting

[1]Tashiro, S. A new method and apparatus for the estimation of exceedingly minute quantities of CO_2. American Jour. Physiology, vol. 32, No. 2, 1913.

corals, and dredging to ascertain the lower bathymetric limit of the species that live on the reefs.[1]

Of the 171 colonies measured in 1912, 135 were artificially planted and 36 were living naturally attached. Of the planted colonies 115 were remeasured in 1914, of which 11 were not thriving, and 34 of those naturally attached. Therefore, of 171 colonies there were 138 which gave satisfactory data on growth-rate for a two-year period.

The Andros Island barrier reef was inspected from High Cay to Middle High Cay, or (as it is locally known) Little Golding Cay, and nearly a week was spent in the lagoon channel off Cocoanut Point. No special addition was made to the information obtained in 1912 on the locus of the different species of corals, but the basis for discussing the subject was extended. Dr. Mayer employed Mr. J. A. Kemp, of Nassau, to collect in the vicinity of Cocoanut Point, and although high winds prevented work on the seaward face of the barrier, suites of specimens representing about 30 species of corals were obtained. Several additions were made to the list of species previously obtained in the vicinity of South Bight, while a few forms obtained at the latter locality were not collected at the former. The number of Bahama shoal-water species represented by the present available collections is about 35, which is probably near the limit of the number that occurs there. There should be a few more than 40 species. Collections in the U. S. National Museum from Florida, and from the Bermudas, Cuba, Porto Rico, and other West Indian localities, can be utilized in extending the account of the west Atlantic shoal-water coral fauna.

Dredging to ascertain the lower bathymetric limit of the shoal-water species was done off Nassau, in water from 4 to 20 fathoms in depth; 6 of 12 hauls were successful. The results were as follows:

List of corals dredged off Nassau, Bahamas.

Species.	Depth (fathoms).
Stephanocœnia intersepta (Esper)	4–9
Dichocœnia stokesi Milne Edwards and Haime	12–17, 12–16, 16–20
Mussa aff. dipsacea Dana	9–10
Siderastrea siderea (Ell. and Sol.)	4–9
Agaricia aff. purpurea Lesueur	12–17
Porites furcata Lam. (Auct.) (dead specimen)	12–17
Porites astreoides Lam	12–17
Millepora alcicornis Linn	4–9, 8

The first number of the couples is the least and the second the greatest depth recorded during the haul. No corals were obtained by a haul in water 20 fathoms deep.

FLORIDA.

The following list of desiderata for the completion of the program laid out for the study of the Florida corals was published in the Year Book for 1913, p. 183: (1) to continue the growth observations for at least two more seasons; (2) to complete the inspection of the Tortugas area for the location of the reefs, coral patches, etc.; (3) to dredge from shoal water to a depth of 50 fathoms, take temperature readings, and collect bottom samples; (4) to conduct experiments on the minimum and maximum salinity (amount of dilution and concentration of sea-water) corals will endure; (6) to conduct additional

[1]The results of the geologic investigations are given under a separate title, which follows.

experiments on the exclusion of light from shoal-water corals; and (7) to ascertain the length of the free-swimming larval stage of several other species. The need of more information on decrease in temperature with increasing depth of water and on the range of variation in the salinity of the water along the Florida reef tract was mentioned. Attempts were made to provide for the indicated deficiencies in information.

The Bureau of Fisheries, in cooperation with the Coast and Geodetic Survey, has recently been conducting investigations between the east coast of the United States and Bermuda, Bahamas, and Cuba. and has promised a copy of the temperature records for use in my proposed account of the ecology of the Florida and Bahama corals as soon as they are available; and Dr. Mayer has consented to make a series of experiments on the upper and lower temperature limits at which corals will take food. With these two supplements to data already accumulated a satisfactory treatment of this aspect of the ecology of the corals in this area should be possible.

Mr. R. B. Dole, of the U. S. Geological Survey, kindly consented to titrate and report on a series of daily water samples from some place along the line of the Florida reef. Through an arrangement between the Bureau of Fisheries, the Lighthouse Bureau, and the Geological Survey, samples are being collected daily at Fowey Rock, off Miami. Mr. Dole will also make quantitative determinations of calcium in Florida sea-water.

During the past season at Tortugas I conducted experiments on the amount of dilution of sea-water the common reef species would endure, with the following results:

Effect of diluted sea-water on Florida reef corals.

Species.	Effect of sea-water of salinity 18.28.[1]			Effect of sea-water of salinity 27.87, 48 hours.
	6 hours.	12 hours.	24 hours.	
Dichocœnia stokesi	None.			
Eusmilia aspera	Pale, damaged	Damaged, partly macerated.	Killed	None.
Oculina diffusa	None	...do	About half macerated.	Do.
Orbicella annularis	Pale	Pale	Killed	Do.
Orbicella cavernosa	None	...do	Pale	Do.
Favia fragum	...do	...do	Slightly pale.	Do.
Mæandra areolata	...do	None	None	Do.
Mæandra strigosa	...do	Pale	Pale	Do.
Mæandra clivosa	...do	None	...do	Do.
Manicina gyrosa	...do	...do	...do	Do.
Siderastrea radians	...do	...do	None	Do.
Siderastrea siderea	...do	...do	Slightly pale.	Do.
Agaricia purpurea	Damaged	Killed	Killed	Do.
Acropora muricata (cervicornis).	None	...do	...do	Do.
Porites clavaria (Auct.)	...do	None	Scarcely damaged.	Do.
Porites furcata (Auct.)	...do	...do	...do	Do.
Porites astreoides	...do	...do	None	Do.

[1]Salinity determination, by R. B. Dole.

The experiments show that for most species of Florida reef corals 24 hours in about 50 per cent sea-water is either beyond or near their limit of endurance; while they will endure a little less than 80 per cent for a long period, and

apparently could live in water of considerably lower salinity than prevails in coral-reef regions. As the lowest recorded salinity in Fort Jefferson moat after a heavy rain was only 32.14, it is evident the corals, even in a lagoon, are running no great risk of being killed by dilution of sea-water through access of rain-water.

Because of the difficulty of concentrating a sufficiently large quantity of water for properly keeping the specimens of corals, experiments with concentrated sea-water were not tried. Furthermore, as the dilution experiments accorded with the results obtained from similar experiments by students of other organisms, it seems safe to infer that although corals will live in considerably diluted sea-water they will not endure a concentration much greater than the highest recorded for Tortugas water, which is 36.29.

A series of experiments was made to ascertain how long the common species of corals would endure the exclusion of light by placing specimens in a light-proof live-car. They were put into the live-car on June 14 and examined on June 28. On July 12 Dr. Mayer reexamined the specimens left in the car and reported their condition as stated in the column headed "28 days," and he again examined them and reported their condition on July 27, as given in the column headed 43 days.

Effect of exclusion of light on Tortugas corals.

Species.	14 days.	28 days.	43 days.
Dichocœnia stokesi	Pale	Reddish brown, but alive.	Alive; reddish brown.
Eusmilia aspera	...do	Very pale, light brown; not quite dead; polyps retracted.	One of 2 specimens dead; live one very pale; polyps retracted.
Oculina diffusa	...do	Very pale brown, but alive.	Nearly all dead; a few polyps alive but retracted and completely bleached.
Orbicella annularis	Nearly killed; some tissue left.		
Orbicella cavernosa	Pale	Nearly white; plant cells dead, but alive; polyps expanded.	Alive, but colorless.
Favia fragum	...do	Dead, macerated.	
Mæandra areolata	...do	Pale, but alive	Both of 2 specimens alive.
Mæandra strigosa	...do	Very pale, but alive	Paler, but still alive.
Mæandra clivosa	...do	...do	Colorless, but still alive.
Manicina gyrosa	...do	...do	Almost colorless, but alive.
Siderastrea radians	...do	Somewhat pale, but alive.	Very pale, but alive.
Siderastrea siderea	...do	...do	Do.
Agaricia purpurea (from Loggerhead Reef).	Part of one colony killed.	Dead.	
Agaricia purpurea (from off Garden Key).	Pale	Dead.	
Acropora muricata (cervicornis).	Killed; tissue nearly all macerated.		
Porites clavaria	Pale	Very pale, but alive	Colorless, but alive.
Porites furcata	...do	2 or 3 specimens dead; the one alive very pale.	Not found.
Porites astreoides	...do	Pale, but alive	Bright olive green; both of 2 colonies alive, but dying around the bases.

Considerable attention was devoted to continuing the inspection of the bottom in and around the Tortugas for the location of coral heads, reef patches, etc. As there is no limit to the detail in which such an inspection may be made, it can scarcely ever be regarded as complete, but as all the shoals of the area have been examined in more or less detail, the local distribution of corals has been ascertained with moderate thoroughness.

Dredge hauls were made in Southwest Channel, east of Pulaski buoy, north of the outer end of Northeast Channel, off Loggerhead buoy, in Southwest Channel, and at several places in the northern part of Tortugas lagoon. The material obtained in the five successful hauls, when supplemented by that previously procured by Dr. Mayer and Mr. John B. Henderson at three other stations, gives a good representation of the corals occurring between 8 and 16 fathoms. No corals were obtained in 20 fathoms, probably because of the soft mud bottom. Bottom samples were taken while dredging. As the species of corals were not listed as they came aboard the yacht, a table of the names of the species with the depths can not now be presented, but it may be stated that specimens of about 15 species were procured at depths greater than 8 and less than 20 fathoms.

Successful dredge hauls were also made on the 6½ to 10 fathom shoal, which lies about 7 miles west of Loggerhead Key. This is a rocky shoal, largely covered by dead coral, mollusk shells, and other calcareous débris.

Measurements and records of the growth of corals artificially planted or living naturally attached at Tortugas were repeated. All the living planted corals except those which had settled in planula cultures or had attached themselves at a known time were taken up and shipped to Washington, as were also some of the colonies naturally attached. Except one tile, all colonies resulting from culture experiments were replanted, in the hope of measuring them a year hence. These colonies are from planulæ that settled in 1910 and in 1915 will be 5 years old. Except the remeasurement of these colonies, the study of growth-rate is now discontinued.

One attempt made at Tortugas failed. It is very desirable to ascertain accurately the duration of the free-swimming larval stage of *Acropora*, but none of the specimens brought into the Laboratory were extruding planulæ. The object in procuring this information is to explain the absence of the genus in the Bermudan fauna and its apparent absence in the Hawaiian Islands. I ventured the suggestion in my monograph, "Recent Madreporaria of the Hawaiian Islands and Laysan," that it is perhaps due to the free-swimming stage being of short duration.

The season of work just ended terminates the field studies I purpose making on the Florida and Bahaman shoal-water corals, by practically completing the program I had laid out when I accepted Dr. Mayer's invitation in 1907 to undertake such an investigation, except that I hope in 1915 to remeasure the colonies reared from planulæ and if occasion presents itself I will inspect parts of the Florida reef which bad weather has previously prevented my seeing. Before I can write the account of the Florida reef corals and their ecologic relations in the way I have contemplated, the additional data on the temperature gradient of the water with increasing depth and the range of variation in salinity along the reef tract should be available. Additional collections of corals south of Fowey Rock are needed and a collection from the island of St. Thomas is essential to settle some disputed points in taxonomy, as several of the types of Duchassaing and Michelotti came from there. However, some of the data for the final report are already assembled and tabulated, and other data may be put into proper form for publication while awaiting the receipt of additional information and the acquisition of additional collections.

Geological Investigations in the Bahamas and Southern Florida, by Thomas Wayland Vaughan.

BAHAMAS.

The study of the bottom deposits along and near the shores of Andros Island was prosecuted with more refinement than in 1912. In order to reach a positive opinion regarding the oolitic or non-oolitic nature of the muds off the west end of South Bight, an elutriating outfit composed of sieves having meshes respectively of $\frac{1}{20}$, $\frac{1}{40}$, $\frac{1}{80}$, $\frac{1}{100}$, and $\frac{1}{200}$ inch in diameter and proper microscopes were taken to the field. A field examination of a bottom sample, No. 177, from 2 miles west of the west end of South Bight, gave the following: *Color:* light gray, tinged bluish. *Reaction to litmus:* strikingly alkaline. *Odor:* fetid, some H_2S. *Cobalt-nitrate test:* showed presence of aragonite.

The following is a description of the separates according to size, but the percentage estimates are omitted, as accurate physical analyses of samples are subsequently given:

Description of separates from bottom sample No. 177.

Held on $\frac{1}{20}$ mesh. Tests of *Orbiculina adunca.*
Held on $\frac{1}{40}$ mesh. Quantities of soft, non-indurated as well as indurated oolite grains, the former easily crushed by a touch with the point of a needle. Foraminifera present.
Held on $\frac{1}{80}$ mesh. Many perfect oolite grains; also foraminifera.
Held on $\frac{1}{100}$ mesh. Many soft oolite grains; foraminifera; fragmental particles.
Held on $\frac{1}{200}$ mesh. Small oolite grains; fragmental particles and fragmental material, predominantly oolitic.
Passed $\frac{1}{200}$ mesh. Quantities of small, globular bodies, minute oolites, and flocculent material.

The separates were compared with the powder of the oolite forming Golding Cay. The mud is clearly oolitic.

The following are accurate physical analyses, made in the Bureau of Soils, Department of Agriculture, of two specimens collected by Mr. Drew in 1912, and of sample No. 177, all of which are oolitic. Specimen No. 87 is from a depth of 6 feet, 1 mile west, and specimen No. 88 from a depth of 12 feet, 2 miles west of the west end of South Bight.

Physical analyses of bottom specimens Nos. 87 and 88.

No.	2 to 1 mm.	1 to 0.5 mm.	0.5 to 0.25 mm.	0.25 to 0.1 mm.	0.1 to 0.05 mm.	0.05 to 0.005 mm.	0.005 to 0 mm.
	p. ct.	*p. ct.*	*p. ct.*	*p. ct.*	*p. ct.*	*p. ct.*	*p. ct.*
87	1.0	1.6	1.7	10.2	25.1	25.8	35.4
88	0.6	1.9	4.3	16.1	27.9	19.5	30.3
177	1.6	4.5	5.0	6.3	12.2	31.1	40.1

Chemical analysis of bottom specimen No. 87, by W. C. Wheeler, U. S. Geological Survey.

	Per cent.
SiO_2	0.28
Al_2O_3	0.03
Fe_2O_3	0.11
MgO	1.25
CaO	52.30
H_2O	3.16
CO_2	42.45
Total	99.58

The calcium carbonate of the specimens comprises both aragonite and calcite.

Dr. J. A. Cushman, of the U. S. Geological Survey, has furnished the following lists of microzoa from samples 87 and 88:

List of microzoa from bottom samples 87 and 88.

No. 87.	No. 88.
A few coral fragments, occasional ostracod valves, and a few foraminifera.	A few shell fragments, coral fragments, ostracod valves, and some foraminifera.
Clavulina angularis.	Orbiculina adunca.
Orbiculina adunca.	Peneroplis pertusus.
Verneuilina affixa.	Peneroplis var. discoideus.
Polystomella striato-punctata.	Verneuilina affixa.
Quinqueloculina, etc.	Polystomella striato-punctata.
	Quinqueloculina and Triloculina.

The results of physical and chemical analyses and lists of foraminifera for the bottom samples collected in 1912 are complete, but a difficult problem remains. As the deposits are composed of calcium carbonate derived through several different agencies, an estimate must be made of the percentage contributed by each agent. In order to make the estimates, criteria for referring the ingredients to their respective sources are necessary. This phase of the investigation is considerably advanced and it is hoped satisfactory results will be achieved.

It has already been stated that the mud off the west side of Andros Island is oolitic and only needs induration to be an oolitic limestone. There are areas on Andros Island underlain by recently emerged oolitic marl or soft limestone, thus permitting the stages of induration to be traced from that of soft mud to that of hard, oolitic limestone.

Bottom samples were collected in the eastern part of South Bight around Golding Cay, and from Mastic Point to Bethel Entrance. The material is distributed in a definite manner behind reefs and other obstructions, in depressions, along the shore, etc. An account of these relations would require more space than is permissible here. One important relation is indicated on Dr. Mayer's map of Bethel Entrance.

The bottom specimens obtained in 1914 have been divided and a portion of each sent to Dr. Frank K. Cameron, of the U. S. Bureau of Soils, who has reported the results of physical analyses. A representative set of samples has been sent to Dr. Albert Mann, U. S. Bureau of Plant Industry, who discovered that in areas of shoal-water calcareous deposits the diatoms are likely to be deficient in silica, having imperfectly developed frustules.

Dr. Karl F. Kellerman, in charge of soil bacteriology and plant nutrition, U. S. Bureau of Plant Industry, has furnished the following preliminary report as to the role bacteria may play in the precipitation of calcium carbonate in the Bahamas and Florida:

"The morphology of *Bacterium calcis* has been determined, showing that the organism is from 1μ by $1\frac{1}{2}\mu$ to 1μ by 2μ and bears a single polar flagellum. On the basis of the position of this flagellum the species is changed to the genus *Pseudomonas*.[1]

"In the sample from Featherbed Bank, Biscayne Bay, Florida, both water and oolitic calcium deposit showed the presence of large numbers of the organism designated by Drew *Bacterium calcis*. No other organisms were sought for in this sample.

"Bottom sample, station 206, 2 miles north of F. E. C. Railway Terminal, Key West, Florida, shows large numbers of *B. calcis*. No other organisms were sought for.

"The second sample from the same locality shows the presence of large numbers of *B. calcis* and also the presence of organisms which produce hydrogen sulphide. While the presence of these organisms has been demonstrated, they have not yet been secured in pure cultures. Organisms which produce a very slight acidity, probably due to carbonic acid, have developed in mixed culture. These have not yet been isolated in pure culture.

[1]Bacterial precipitation of calcium carbonate. Jour. Wash. Acad. Sci., Aug. 1914, p. 402.

"Sample from the Marquesas Lagoon, southwest quadrant, both water and oolitic mud, show the presence of very large numbers of *B. calcis*, ranging from 3,000 to the cubic centimeter upwards. No other organisms have been found in these samples, possibly due to the unusually large number of *B. calcis*.

"Following the procedure outlined by Drew, we have been able to cause a rapid precipitation of calcium in culture media containing calcium acetate or other organic salts of calcium. No precipitation was evident from the organisms growing in natural sea-water or in synthetic sea-water, unless carbon dioxide was introduced either from a gas generator or by growing (in association with *B. calcis*) some bacterium which would produce carbon dioxide and supplying to the culture flask small quantities of sugar or some similar carbohydrate.

"We have notyet definitely determined whether the calcium carbonate produced during the decomposition of calcium acetate is caused directly by the breaking up of the calcium acetate or whether it is due largely to the formation of ammonium by *B. calcis*, together with the absorption of carbon dioxide from the air. In our laboratory, where the supply of carbon dioxide is necessarily at all times rather high in the atmosphere, it is probable that this plays an important role."

As one of the three processes whereby calcium carbonate may be precipitated by bacterial agencies, Dr. Kellerman states:[1]

"The associative action of mixed cultures of bacteria, one species which forms traces of carbon dioxide and one of which forms ammonia either by decomposing some proteid or by reducing nitrates to nitrites and to ammonia, gives rise to ammonium carbonate. This ammonium carbonate reacts with any calcium sulphate which may be in solution according to the formula

$$CaSO_4 + (NH_4)_2CO_3 = CaCO_3 + (NH_4)_2SO_4$$

It is obvious that the carbon dioxide necessary for this reaction may be produced by plant or animal catabolism as well as by bacterial fermentation."

In a mixed culture of this kind Dr. Kellerman suspended a collodion sack containing calcium sulphate, thus maintaining a nearly uniform concentration of calcium sulphate in solution in the water. Grains of calcium carbonate bacterially precipitated under these conditions are spherulitic, with a dark nuclear and a lighter, fibrous outer zone. Many grains formed by the precipitate from calcium acetate clearly show zonal growth.

In June 1913, I began a series of experiments to produce by inorganic agencies calcium carbonate granules which would exhibit zonal structure. The procedure followed was similar to that used first by Rainey. A small amount of gum arabic was dissolved in sea-water to which ammonium carbonate was added. The abundant precipitate of calcium carbonate, which results by the chemical reaction indicated in the quotation from Dr. Kellerman, is nearly all spherulitic in form. After standing for a month or more the liquid was decanted from the precipitate, sea-water containing gum arabic was poured on it, and ammonium carbonate was added. The result of such periodic precipitation was to form concentric shells of calcium carbonate around the previously formed spherulites. In order to make the zonal growth more evident a number of grains formed by the process stated were stained with waterproof red ink and introduced into a solution in which calcium carbonate was subsequently precipitated. This experiment brought out with great distinctness the zonal arrangement of the successive shells.

Considerable attention was paid to the geology of the vicinity of Golding Cay and of Cocoanut Point, Andros Island, and of New Providence Island. The dune origin of Driggs Hill and Golding Cay, Andros Island, was demonstrated. The marine origin of the area of flat land underlain by oolite was proved in 1912. Marine fossils were found in limestone underlying the flat on the landward side of the dune ridges (now consolidated oolite) from Cocoanut Point to Nicollstown, also Andros Island. Marine fossils were found not only along the sea front, but also in Grantstown Plain, south of Lake Kil-

[1]Journal of the Washington Academy of Sciences, vol. 4, No. 14, p. 400, August 19, 1914.

larney near Carmichael, and between lakes Killarney and Cunningham, New Providence Island. In some places the marine oolite is evidently older than the dunes; for instance, a conch shell is reported by Judge Ray from a depth of 10 feet in Nassau at the corner of Frederick and Bay Streets. In other instances certain oolitic deposits are clearly younger than some of the dunes; while in still other instances the age relations are not yet clear and more detailed work than was practicable on the expedition is necessary. It is evident that not all the Bahaman oolites nor all the dune ridges are contemporaneous, and that the formation of both oolite and dunes has been in process for some time. Slightly elevated coraliferous limestone was observed at a number of places along the east front of Andros Island and along the north front of New Providence Island.

Physiographic evidence was procured clearly showing that the last change of sea-level was by a minor uplift of the land. A definite wave-cut scarp, its base standing about 10 feet above water-level, was seen on the south side of the west end of Lake Cunningham. Indefinite suggestions of elevated scarps were seen around the east end of South Bight and in places on New Providence Island. A definite, slightly elevated scarp, with one well-developed sea cave, extends interruptedly from Morgan's Bluff to Mastic Point, Andros Island. Usually the base of the scarp is only 3 or 4 feet above sea-level, but the cave at Nicollstown light indicates an elevation of about 18 feet at that point. The elevation has been accompanied by minor warping. Cracks and joints, probably associated with earthquakes, are visible in the vicinity of Nicollstown. From the additional observations it is evident that in large areas of the Bahamas, specifically Andros and New Providence Islands, the last change of sea-level was through uplift accompanied by warping, to amounts ranging from 1 or 2 to 18 feet. The uplift, however, is subordinate in amount to the antecedent submergence.

Attempts were made to procure additional information on "blue" or "ocean" holes. Under the guidance of Mr. Lenox Forsyth and his son, Mr. E. W. Forsyth, one hole on Gibson (locally known as Hog) Cay in Middle Bight was sounded and found to be 7½ fathoms deep. After our departure from Andros soundings in two other holes were made by the latter and the results have been reported to me. One hole in the open water of North Bight, three-fourths of a mile northwest of Booth Cay, has depths of 31, 32, and 33 fathoms according to four soundings. A second hole is in an area of North Bight, locally known as Fat Turtle Sound. It is almost separated from the open water by a rocky ridge partly submerged at spring tides. Of four soundings, two gave a depth of 9½ fathoms, 30 feet from shore; and two a depth of 11½ fathoms near the center.

Mr. Paul O. Meeres, of Nassau, supplied the following information on one of these holes near Black Point, on the shore of Little Abaco. It is almost circular, with sheer walls to a depth of 10 fathoms. The total depth is not known, but it exceeds 18 fathoms. Gray snappers, tarpon, and other species of fish live in it.

On the assumption that these holes were subaerially formed, parts of Andros must have once stood 192 feet higher than now.

In the report for 1912 I pointed out that the present barrier reef is growing on the edge of a platform which is submerged to a depth of about 2 fathoms, and that some of the "blue" holes occur on this platform between the barrier reef and the shore. The sudden, scarp-like drop to depths "between 4 and 10 fathoms," on the leeward side of the reef, was also pointed out. The accordance in depth of several pot-holes, 36 to 45 feet below sea-level, suggested the presence of a submerged terrace seaward of the barrier reef at a

depth of 8 fathoms or somewhat more. A series of soundings, undertaken east of South Bight from off Bastian Point to off Sharp Rock Point, clearly showed a platform ranging in depth from about 9 fathoms on its landward side to a depth of about 13 fathoms on its seaward edge, where there is a rapid slope to 20 fathoms or more and a steeper declivity into depths exceeding 100 fathoms. This outer submerged terrace can be traced along most of the eastern face of the Andros barrier reef; it is greatly developed on the north side of New Providence Island, especially seaward of Hog Island, and on the east side of the Berry Islands. In fact, this submerged terrace is one of the salient submarine physiographic features of the Great Bahama Bank.

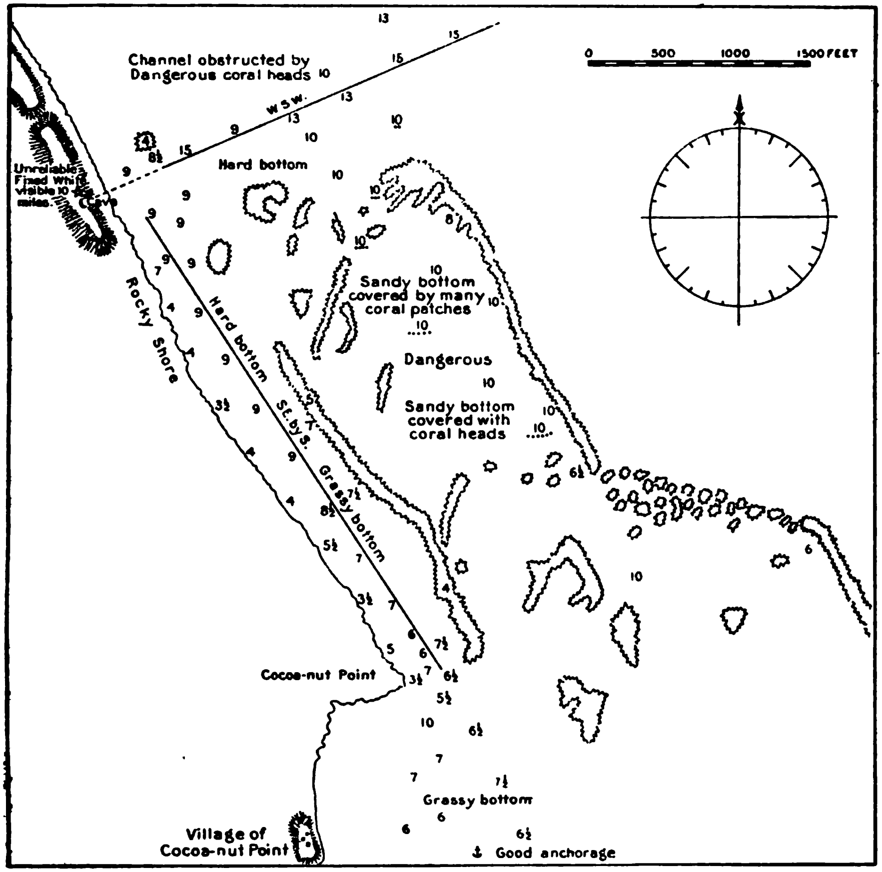


FIG. 7.—BETHEL ENTRANCE, ANDROS ISLAND, BAHAMAS.

Position of light, Lat. 25° 8' N., Long. 78° 0' 30" W. From a plane-table survey by Alfred G. Mayer, May 1914.

As other "blue holes" attain a depth as great as 33 fathoms, a submarine shelf at that or a slightly greater depth might be expected, but the hydrographic work necessary to ascertain whether such a platform exists has not been done.

In my paper entitled "The building of the Marquesas and Tortugas atolls, etc.,"[1] I presented evidence which led to the conclusion that the Tortugas atoll

[1]Carnegie Inst. Wash. Pub. 182, pp. 57-67, 1914.

rim after its formation had been elevated about 50 feet and then depressed. The presence of submerged overhanging cliffs was mentioned and it was stated that the work of subaerial agents should be considered. Studies of the bank around Loggerhead Key showed the bottom to be composed of rock, which is frequently bedded, and whose surface is pitted, jagged, cavernated, and tunneled, with a zone of undercutting the upper edge of which ranges in depth from 16 to 24 feet. As the pits, cavernations, and tunnels resemble those observed, but not carefully studied, on subaerial limestone surfaces, and as the overhanging submerged cliffs suggested that they are cliffs wave-cut at the base and subaerially sculptured on the top, a detailed study of the minor sculpture of the limestone surfaces, both above and within the reach of the waves, was undertaken in the Bahamas, and a considerable body of information, with accompanying photographic illustrations, was accumulated. It was not practicable to reexamine the bottom of theTortugas area with requisite thoroughness to be positive in expressing an opinion as to the origin of the submerged sculpture in that area, but previous observations combined with additional somewhat casual observations strongly suggest submerged surfaces which were sculptured at or above the upper reach of waves, while wave-cut cliffs occur at lower levels.

This line of investigation appears to be of a high degree of importance because of the possible assistance it may render in the interpretation of the geologic history of flat-lying limestone areas. The significance of indented shore-lines and submerged valleys has long been recognized and deductions from them are possible where there are land masses which are of appreciable relief and which are largely composed of non-calcareous material. Calcareous deposits of low relief do not develop conspicuous drainage systems, as the waters form underground tunnels and runways and thus sink below the surface. Therefore, in such areas as southern Florida and most oceanic atolls, as the investigator is deprived of the aid of gross physiographic features in interpreting geologic history, he must seek other criteria, and it appears that needed assistance may be found in the study of the minor sculpture of limestone surfaces and in the application of principles deduced therefrom.

FLORIDA.

The investigation of the bottom deposits of Florida along the reef-tract was continued during June 1914, and samples were collected from a number of additional stations between Cape Florida and Tortugas. Portions of the samples have been sent to Dr. Cameron for physical analyses and to Dr. Mann for a report on the diatoms. Bottom muds and water samples for bacterial study were sent Dr. Kellerman from Featherbed Bank, Biscayne Bay, from a mud flat about 2 miles north of Key West, and from Marquesas lagoon; notes on his results are given on pp. 228, 229.

The study of the shore-line physiography of southern Florida and of the agents shaping and building banks was continued, and certain studies, especially those of currents, were made in some detail.

Some attention was paid to the valley profile and the character of the channel of Miami River at Miami. There is along the stream a low terrace, cut into the Miami oolite, to a level about 10 feet below the general level of the Miami oolite plain. The stream has trenched its channel to a depth of about 9 feet below sea-level. The lower terrace extends to the shore of Biscayne Bay and connects with a low, flat terrace lying between the bay and a slightly elevated wave-cut escarpment which runs from Devil's Punchbowl southward through Cocoanut Grove to an undetermined distance beyond. The seaward face of the keys was inspected from Soldier's Key to Knight's Key.

Current measurements were made with Ekman meters at 19 stations. The readings were made by Mr. John Mills, chief engineer, Mr. George Tracy, sailing-master of the *Anton Dohrn*, and Mr. W. M. L. Wilson, in charge of the launch *Velella*. The records clearly show a westward set of the current in Hawk Channel and south of Tortugas.

The cross-section of Loggerhead Key and the spit at its south end were remeasured so as to record changes in the position of the shore-line. A plane-table survey of the shore-line of the key, on a scale of 500 feet to 1 inch, is here reproduced on a reduced scale. A geologic map of the key was also made.

As I am preparing an article on the effect of currents on the shore-line physiography of southern Florida and on the building and shaping of keys and banks, no more detail will here be given on these subjects.

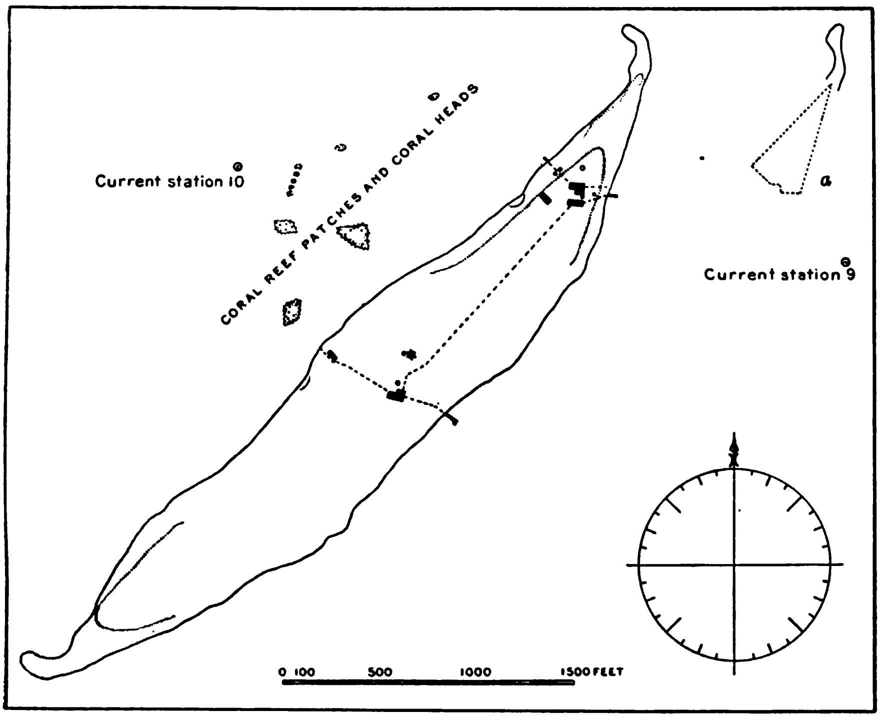


FIG. 8.—LOGGERHEAD KEY, TORTUGAS, FLORIDA.

Lighthouse, Lat. 24° 38′ 04″ N., Long. 82° 55′ 42″ W. From a plane-table survey by T. Wayland Vaughan, June 10–13, 1914.

a, North spit of key, June 21, after swell from west, June 16–18.

DEPARTMENT OF MERIDIAN ASTROMETRY.*

BENJAMIN BOSS, DIRECTOR.

As in previous years, the work of the Department of Meridian Astrometry falls principally under three headings: investigation of stellar motions, observations, and reduction of observations.

INVESTIGATIONS OF STELLAR MOTIONS.

The investigation of the dependence of solar motion upon the type and the mean magnitude of the stars employed has been finished, as far as present data would permit. The published results indicate the following conclusions:

1. There is little if any shift in galactic longitude in the position of the apex of solar motion dependent upon the mean magnitude of the stars employed in its determination, though a slight and possibly fictitious shift in galactic latitude is noted.

2. There seems to be a considerable dependence of the position of the apex of solar motion upon spectral type, probably due to a relative shift between early and late type stars. It manifests itself in a separation in galactic longitude of about 12° between the positions of the solar apex as derived from early and late type stars, the galactic latitude remaining constant at about +22°. The evidence on this point is satisfactorily corroborated by a similar treatment of radial velocities. It also manifests itself in a difference of about 6 kilometers between the values of solar velocity as determined from early and late type stars.

3. There is a systematic difference between the position of the apex of solar motion as determined from proper-motions and that determined from radial velocities, apparently of the same order as the difference due to types.

4. The close agreement of the solar apex as deduced from B-type stars from both proper-motions and radial velocities indicates one of two extremes. Either the small real velocities of these stars fit them especially for a solar-motion determination, or there exists among them a one drift which entirely unfits them for such a determination. Until the real cause of the agreement can be established it might be advisable to exclude the B-type stars from the determinations of solar motion.

5. If there is any real effect on solar motion due to the distribution of the stars according to galactic longitude or latitude, the existing material is not capable of revealing it.

6. In the future, discussions of solar motion should take into account the effect of spectral type, as manifestly a change in ratio between early and late type stars will cause a shift in the position of the solar apex. It might be well temporarily to adopt as the position of the solar apex a mean value between early and late type solutions: A = 272°,

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D = +35° from proper-motions; A = 266°, D = +25° from radial velocities; or for general purposes, the position A = 270°, D = +30°.

Aside from the results published, solutions have also been made for subdivisions of each type according to magnitude. The completed solutions for the two subdivisions $0^{M}.$ to $5^{M}.2$ and $5^{M}.3$ to $6^{M}.0$ are ready for publication, but for stars of fainter magnitude the types are not available. Publication will therefore be delayed until the completion of the Harvard classification.

Directly related to the foregoing investigation is one by Mr. H. Raymond, dealing with preferential motion according to type. Mr. Raymond based his investigation on 6,033 proper-motions from the Preliminary General Catalogue, treating them according to Schwarzschild's method. The proper-motions were successively grouped according to type, according to hemispheres, and again by type according to galactic and non-galactic latitudes. A summary of his results follows:

1. The vertices for the various groups lie in a band making a small but well-marked angle with the galaxy, practically in the direction of solar motion. The vertices for the early types A and F and those for the late types K and M lie somewhat separated from each other near the two ends of this band. Type G, as in the case of solar motion, is anomalous. As a similar phenomenon is exhibited in the determinations of the apex of solar motion, the question arises whether the determination of apex and vertex are completely independent of each other. Mathematically the recognized methods seem to be sound; but they rest upon assumptions in regard to the areal and radial distribution of the stars, the similarity of motions in different regions, and the laws of distribution of those motions, which can hardly be true, save in the roughest way. The distribution of vertices is nearly along a meridian. If, however, it were due to errors in the proper-motions in declination, it should also appear in the solution by hemispheres. It is difficult to believe that errors of sufficient size could exist, varying with type but not with position in the sky.

2. The range of galactic and non-galactic solutions, for each group, falls, when at all large, into the same belt. Type G is again anomalous, in regard to both the amount and the direction of the range. Anomalies seem more frequent for non-galactic than for galactic stars. These results can claim no great accuracy, especially for the smaller types.

3. The ratios of the mean velocity in the direction of preferential motion to that at right angles to that motion show, rather uncertainly, that the preferential element of motion is stronger in the earlier types, and within the earlier types, for non-galactic stars; and decisively that it is stronger for large proper-motions.

4. Attention has been called to the fact that the proper-motions of the earlier type stars are greater in the non-galactic than in the galactic regions. It has been suggested that the velocity-figure for these stars might be an ellipsoid of three unequal axes, thin in the direction of the

galactic poles. If such were the case, the ratio of axes in the projected ellipse should be least in the galactic region, which is contrary to the testimony of this investigation. The evidence, such as it is, tends to the conclusion that the proper-motions within and those without the galaxy are differently distributed, the non-galactic ellipsoid being for early types more prolate. This favors the idea that the the non-galactic stars are outside the galaxy as the result of a selective process.

5. The well-known increase of velocities with advancing type is distinctly shown. If account be taken of the value of solar velocity as derived from the separate types, the increase in the semi-axes of the velocity-figure, and consequently in the peculiar motions, is still more marked, and is progressive through type F.

What may prove to be a vertex of preferential motion for small proper-motion stars within the galaxy has been found. The directions of motion of four groups of stars, two of which are the Pleiades and Præsepe groups, converge sharply at a point in R. A. $=4^h\,45^m$, Decl. $= -15°$. Each group, besides agreeing as regards amount and direction of proper-motion, is largely composed of early-type stars, which for the most part lie in or near the galaxy. As it has been shown that the large proper-motion stars lie in great part outside the galaxy and that the vertex of preferential motion determined from them is quite distinct from the vertex derived from treatment of stars of average proper-motion, both within and without the galaxy, it is probable that the slow-moving galactic stars will furnish still another vertex of preferential motion.

In order to make a complete investigation of the phenomenon all parts of the sky were treated for a possible preferential motion toward the given vertex. By plotting the regions where such effects were shown, it soon became manifest that a belt was described coincident with that in which lie the majority of the bright B-type stars and the thickly clustered A-type stars. Consistently with the theory of preferential motion, there was no manifestation of the phenomenon in those portions of the belt more nearly approaching the vertex or antivertex.

In order to further test the supposition that the preferential motion is mainly confined to the bright belt, all regions 90° from the convergent point were examined. The preferential motion should be a maximum in such a zone. Only 11 per cent of the zone showed a marked evidence of the phenomenon sought, and only 26 per cent showed some evidence. Rejecting the region common to the two belts, only 8 per cent showed strongly the effects of preferential motion and only 14 per cent some evidence. On the other hand, considering that portion of the bright belt where preferential motion might be expected to be evidenced, 54 per cent shows the effect strongly and 77 per cent shows some effect. It may therefore be concluded, with a reasonable degree of certainty, that a portion of the early-type stars in the galaxy exhibit a preferential motion toward a vertex at R. A. $=4^h\,45^m$, Decl. $= -15°$.

In the Astronomical Journal, Nos. 635–636, a group of stars was

pointed out whose motion is very nearly directed toward the antapex of solar motion. The absolute agreement between the observed mean proper-motion of groupings arranged according to distance from their convergent, and the value of the proper-motion computed on the basis of true parallelism of motion of the group, pointed to a physical connection between its members. The radial velocities of six stars furnish a further criterion for the reality of the group. They were found to satisfy the conditions of the hypothesis, if we assign a velocity to the group of 21 kilometers per second relative to the sun.

The location of the convergent point of the group, taken in conjunction with the group velocity, indicates that we are dealing with a group of stars practically at rest in space. Observed parallaxes were only available for two stars, but in both cases the agreement with the computed value is well within the probable error of determination. From the computed parallaxes it appears that the stars of the group are relatively near the solar system.

The solution for solar motion by zones of galactic latitude furnished a very discordant direction for solar motion in the case of the treatment of the south galactic polar region. Analysis of the proper-motions in this region disclosed a startling dissimilarity between the distribution of the motions of early and late type stars. For stars whose proper-motion does not exceed 20″ per century the ratio of the cross-motions + to − is 5.8 for type A, 0.2 for type G, and 0.5 for type K. For large proper-motions the ratio is 1.4 for type F, 0.6 for type G, and 0.3 for type K. Radial velocities for early-type stars in the region of the south galactic pole are scarce, but what evidence there is points toward a relative drift between early and late type stars. The discussion has not been entirely finished.

Following is a summary of a paper by Dr. Albrecht, who has been continuing his study of standards of wave-length:

Stellar radial velocities are known to contain systematic errors. These may be separated into two divisions: (*a*) systematic differences between the results for the same stars as observed at different observatories, and (*b*) systematic differences dependent upon the stellar spectral type, which were found by Campbell and designated by the letter K. The former must clearly be due to causes within the control of the observer, *i. e.*, the instruments and the methods of measurement and the reduction of the spectrograms. The latter are due in part to these same causes, though they may—and probably do—depend also upon causes within the stars themselves.

Owing to the great perfection of modern stellar spectrographs, errors from instrumental causes must be nearly negligible. Dr. Albrecht has previously shown: (1) that a large percentage of the spectrum lines vary in wave-length progressively as a function of the stellar spectral type; (2) that for many of the lines—and these must be used for the determination of the stellar radial velocities—the laboratory values of

the wave-lengths are not sufficiently accurate to meet the requirements of the radial velocity observer. This leads unavoidably to the inference that the systematic differences in the radial velocities under division (*a*) above are due in major part, if not entirely, to the adoption by different observers of different wave-lengths for the same lines. A discussion of the systematic differences between the radial velocities as determined at the Lick and Bonn observatories shows that this is true for these two observatories.

Systematic differences in radial velocities.

Type.	Kustner's observed (Lick-Bonn). A	Kustner's adopted (Lick-Bonn). B	Ludendorff, for Bonn First Series (Lick-Bonn). C	Due to wave-lengths used (Albrecht-Bonn). D	No. of lines on which D is based.
	km.	*km.*	*km.*	*km.*	
F5	+0.23	0.0	0.0	+0.43	38
G	+0.15	0.0	−0.6	−0.46	45
G5	−1.06	−1.0		−1.19	46
K	−1.42	−1.4	−1.1	−1.29	50
K5	−2.30	−2.3		−1.60	46
M	−2.78	−2.8	−2.4	−1.77	35

From (1) and (2) it is evident that the systematic errors K, dependent upon stellar spectral type, will require revision. At present it is not feasible to separate the portion of the K-term that is due to the use of erroneous wave-lengths from the portion that may be due to causes within the stars themselves. In another connection Dr. Albrecht has been engaged in the determination of standards of wave-length for each stellar spectral type. When these are completed it will be possible to attempt the separation referred to.

OBSERVATIONS.

As heretofore, each observer, together with a microscope reader, has been on duty for a week at a time. There were 116 nights on which observations could be taken, the total number of observations amounting to 16,678. The observations were divided among the observers as follows: S. Albrecht, 3,999; B. Boss, 330; A. J. Roy, 6,838; W. B. Varnum, 5,511. The circle-readings for zenith distance have been distributed as follows: S. B. Grant, 6,141; A. R. Guy, 256; H. Jenkins, 4,808; H. Raymond, 5,473. Following the notation used in previous reports, the observations were distributed AE 5,443, AW 4,849, BE 3,347, BW 3,039. Some portions of the observing list are nearly completed as far as the miscellaneous stars are concerned, but two cloudy winters have interfered with that portion of the program. Special efforts will be made to bring up the arrears.

The observing list has been slightly enlarged, consistently with the original plan, by the addition of stars shown by the Greenwich Catalogue of 1900 to have a centennial proper-motion of 10″ or more. A few stars have been added from other sources.

REDUCTION OF OBSERVATIONS.

The definitive clock-rates have been applied to all of the right ascensions of the 87,000 San Luis observations, and the formation of the final places is well under way.

Pending the completion of the examination of the individual microscope readings, little has been done toward the final reduction of the San Luis zenith distances. To date, about 71,000 of the 87,000 zenith-distance observations have been critically examined. For the circle opposite the clamp, all the microscope readings have been inspected. From about 170,000 individual readings, 274 errors were detected, mainly 5″, 10″, or greater. The 5″ errors, which occurred in the greatest abundance, would have been difficult to detect in the final reduction, so that the zenith distances will be greatly improved by the examination now nearly finished. Incidentally 108 errors in means and 41 misapplications of division corrections were caught during the process of the examination, a distinct help to the future reductions.

For the current work the reductions to mean wire have been kept well up to date. As the material accumulates, a close check has been kept on the fixity of the wire intervals. The errors of runs of the microscopes have been determined as usual and some progress has been made towards taking means and applying to them the runs and division corrections. The readings made last year on circle A for the determination of its eccentricity have been utilized in the formation of a table for the further examination of the readings of single microscopes.

Some progress has been made in entering new observations on the card catalogue.

In the report of this department, as given in the Year Book No. 11, the collimation of the meridian-circle telescope was treated as a linear function of the temperature. Some account was taken of a possible lag through adopting the temperatures of the thermometer incased in the barometer box. The probable-error of the resulting collimations was so small that it was deemed unnecessary to employ further refinement. Since the return of the instrument from San Luis the collimations have been so discordant that it seemed imperative to further investigate them.

Dr. Albrecht has treated the Albany collimations graphically, on the assumption of a temperature gradient term. Virtually a temperature coefficient of $-0\overset{s}{.}005$ was applied and the residuals grouped according to morning and afternoon observations. This showed a distinct difference, indicating the possibility that the collimation contains a temperature gradient term. By graphical methods the relation of collimation to change of temperature was determined and a smooth curve drawn. By process of trial, an equation was derived to fit the curve. Attention was called to the possible existence of errors of this nature in the results for collimation obtained at other observatories.

On the other hand, Mr. Roy has noted a decided effect of the nature of lost motion. On a number of occasions, when there has been a decided rise or fall of temperature, the collimation has remained practically stationary. The same was found to be the case when the observations were taken at or immediately following the maximum temperature of the day. The collimation appears to remain constant when the temperature fluctuates within a range of about 22° C. Under this hypothesis change in collimation would be dependent upon the extreme daily range of the temperature. Whenever the temperature varies sufficiently to take up the lost motion there is a change in the collimation. It is only at such times that a gradient or lag term would become effective. Observations have been planned to thoroughly investigate the matter.

Mr. Jenkins has published the results of a survey of the San Luis photometric determinations for the purpose of noting large discrepancies in the observed values. The list contains stars for which the San Luis observations are discordant; stars whose magnitudes as measured at San Luis differ considerably from those given by Harvard, and a few others whose magnitudes differ with Gould's. While part of the discordances may be attributed to abnormal measurements, there is considerable probability that some of these stars are variables.

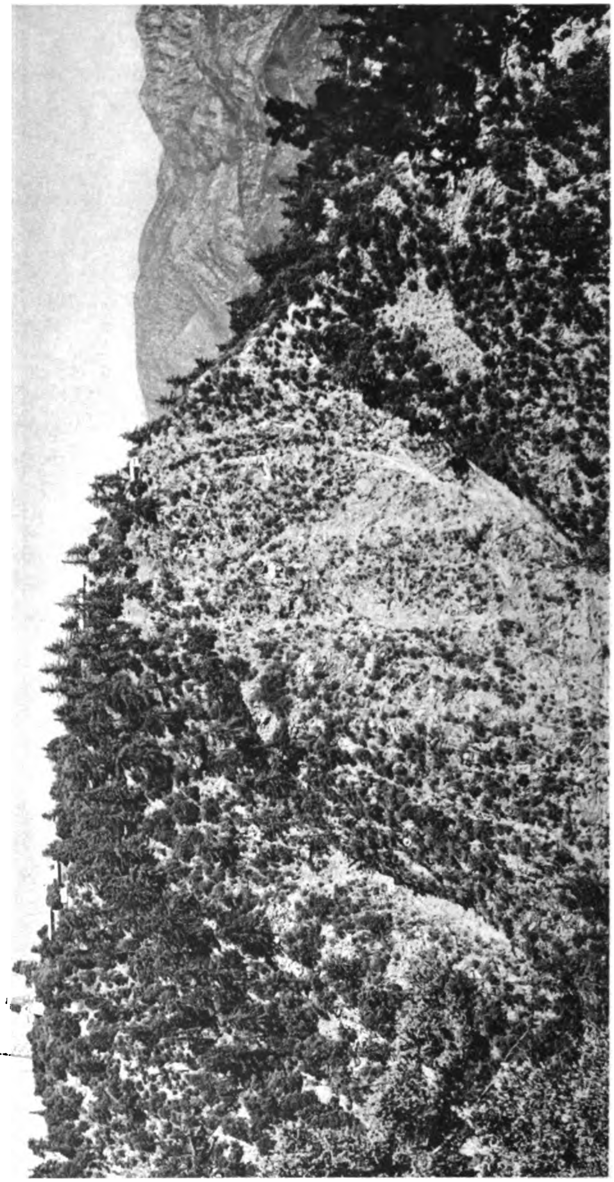
The printer's manuscript for the zone catalogue of observations undertaken during the years 1896 to 1900 has been thoroughly checked. The comparison with other catalogues has been completed and proper-motions computed for all stars where this motion amounts to 10″ per century. Many stars with an indicated motion slightly in excess of this limit were excluded because of large probable error. Of the more than 700 proper-motions, about 100 were either under 10″ or so slightly above that limit as to indicate that they may eventually prove to fall under the limit. With few exceptions stars were not considered if they had but one authority antedating the Albany observations.

APPARATUS.

The new Riefler clock, No. 218, has been secured and mounted in position. It is of the latest type, free escapement, nickel-steel pendulum with compensation of temperature and its stratifications, electric winding, and arranged to break the chronograph circuit every second. This clock will in the future serve as the standard clock.

The system for temperature control of the clock-room has been installed. Several difficulties in the proper operation of the system have been overcome, but it is still desirable to change the operative power of the automatic switch employed in the system. The thermograph records of the clock vault indicate a very small variation of temperature, the record being practically a straight line.

PLATE 4



The Observatory on Mount Wilson.

MOUNT WILSON SOLAR OBSERVATORY.[1]

GEORGE E. HALE, DIRECTOR.

A vigorous revival of solar activity, after a prolonged period of calm, marks auspiciously the opening of the second decade of the Observatory's existence. We are now applying the instruments and methods devised and tested in previous years to the study of great sun-spots and other solar phenomena, hitherto investigated with inadequate means. New and interesting results have already been obtained, and the outlook for the future is most promising.

As a brief outline of the work of the first decade will soon be published elsewhere,[2] we need not pause to summarize it here. The year just closed has been one of the most productive of this period. Solar research has progressed satisfactorily, and a beginning has been made in the application to solar phenomena of Stark's capital discovery of the effect of an electric field on radiation. In stellar astronomy the year has brought new conclusions of the first significance, the most important of which promises to furnish the means of determining a star's distance simply by measuring its brightness and the relative intensities of certain lines in its spectrum. The laboratory investigations have been signalized by results which will greatly aid in the interpretation of both solar and stellar phenomena, and the work of construction has gone forward rapidly.

Before proceeding to a detailed account of the labors of these various departments, we may briefly enumerate the principal conclusions to which the investigations of the year have led:

(1) Twenty-five lines, all originating at comparatively low levels in the solar atmosphere, have been found to show the existence of the sun's general magnetic field. These represent the elements iron, chromium, vanadium, and nickel (in addition to one unidentified line), but there is every reason to suppose that other low-lying elements will also be included later.

(2) The measures show that the vertical intensity of the general field at the poles varies from a value of 55 gausses for the weakest lines (intensity 0) to 10 gausses for the strongest lines (intensity 5) yet found to show the effect.

(3) A preliminary attempt to detect the Stark effect due to electric fields in sun-spots has hitherto yielded no positive results.

(4) Accurate tests of the hydrogen lines for plane polarization, made under the highest dispersion with a Nicol and compound half-wave plate, indicate that their increased width near the limb (as compared

[1]Situated on Mount Wilson, California. Address, Pasadena, California. (For previous reports see Year Books Nos. 3–12.)
[2]Under the title "Ten Years' Work of a Mountain Observatory."

with the center of the sun) is not primarily due to the Stark effect. Any residual influence of an electric field must be extremely small, demanding special methods of measurement for its detection.

(5) Further studies have emphasized the significance of the opposite magnetic polarity which characterizes the principal members of binary spot-groups.

(6) Before and after the recent sun-spot minimum, the preceding (or following) spots of bipolar groups have been found to be of opposite polarity in the northern and southern hemispheres.

(7) In each hemisphere the high-latitude spots of the new cycle are opposite in polarity to the low-latitude spots of the old cycle.

(8) On "flash" spectra taken without an eclipse 1,024 bright lines have been measured. These surpass in number the "flash" lines photographed in the same region at eclipses and represent a lower level in the solar atmosphere.

(9) Double reversal universally characterizes the stronger dark solar lines in these spectra.

(10) Elements of high atomic weight are found to lie below the level of iron and other lighter elements, in harmony with previous results.

(11) As there appears to be no clear evidence of systematic displacement of the bright lines, the results do not support the hypothesis of anomalous dispersion.

(12) The dark-line spectrum on these plates differs remarkably from that of the sun's center, notably in the great weakening or strengthening of certain lines and the appearance of a few new ones.

(13) An apparent band spectrum, possibly due to magnesium hydride, has been found between $\lambda 5050$ and $\lambda 5150$.

(14) A preliminary study of the displacements of solar lines at the sun's center gives no evidence of the existence of the gravitational shift toward the red predicted by Einstein.

(15) The results are equally opposed to Julius's anomalous dispersion theory.

(16) A discussion of the displacements indicates that in the higher levels of the solar atmosphere they are due to downward velocity of the vapors, which decreases toward lower levels and finally vanishes.

(17) Below the level of solar lines of intensity 4 or 5 the effect of pressure appears, increasing rapidly from about one atmosphere to considerably higher values at greater depths.

(18) The great mass of the vapors comprising the solar atmosphere is condensed within a very thin layer close to the photosphere.

(19) A new discussion of Mitchell's eclipse spectra yields results in complete harmony with those derived from radial displacements in spots.

(20) These "flash" spectra indicate levels for iron lines ranging from 275 kilometers for lines of intensity 00 to 806 kilometers for lines of intensity 10–40.

(21) The discussion has brought out many new facts relating to the enhanced lines in the chromosphere.

(22) Five photographs of Hind's Variable Nebula in Taurus indicate no changes which may not be attributed to differences in the quality of the plates.

(23) The object N. G. C. 6760, described as a variable nebula, has been found to be a star-cluster showing no traces of nebulosity.

(24) The first complete determinations of stellar parallax with the 80-foot Cassegrain combination of the 60-inch reflector are very satisfactory.

(25) The measurement of the magnitudes of some 600 stars near the North Pole establishes the photographic scale from the second to the twentieth magnitude.

(26) As previously found, the magnitudes are in close agreement with the Harvard results for the interval 10.5–15.5, but there are divergences for both bright and faint stars.

(27) A determination of the photovisual scale for magnitudes 2 to 17.5 has been made.

(28) A comparison of photographic and photovisual magnitudes shows that the minimum color index of the whitest stars increases with increasing magnitude, indicating that the fainter stars are redder than the brighter ones.

(29) A determination of the photographic and photovisual light curves of the cluster-type variable star RS Boötis indicates a marked change of color with magnitude, in harmony with observations of a simultaneous change in spectrum.

(30) The total number of constant-velocity stars for which radial velocities have been determined is now 545, an increase of 173 during the year.

(31) The velocities of 100 parallax stars published since the last report are of special interest. Twenty of these (corrected for the sun's motion) exceed 50 km. and 6 exceed 100 km., the highest being 319 km.

(32) Two A-type stars of high constant velocity (over 100 km.) have been found.

(33) Several pairs of optical double stars are indicated by their equal velocities to be physically connected.

(34) The star O. Arg. S. 14320 is found to have the enormous velocity in space of 577 km. per second.

(35) There have been 16 new spectroscopic binaries discovered, making the total number 115.

(36) Comparative photographs on the same plate of the spectra of near and distant stars show that the latter are, in general, much fainter in the violet.

(37) Photometric measures of 151 photographs of stellar spectra confirm this result, and show that the amount of the effect depends upon the spectral type, being twice as great for K_0–K_4 stars as for F_0–F_9 stars.

(38) As the average differences of proper motion for the groups observed in each case are closely the same, the observed effect for these stars must be due mainly to differences in physical condition.

(39) The hydrogen lines are abnormally strong in certain small proper-motion stars. This is due mainly, if not wholly, to the physical condition of these stars, and not to hydrogen gas in space.

(40) Certain other spectrum lines are weak in the large proper-motion stars and strong in the small proper-motion stars, and conversely.

(41) The relative intensities of these lines have permitted the absolute magnitudes of known-parallax stars to be computed. The method promises to give a satisfactory means of determining a star's parallax from the relative intensities of these lines when its apparent magnitude is known.

(42) The observed disappearance of the chief nebular lines makes the spectra of Nova Aurigæ and Nova Persei identical with those of certain Wolf-Rayet stars, suggesting that the latter may be temporary stars in the later stages of their history.

(43) Twenty stars in the cluster M 13, in addition to those previously reported, have spectra ranging from A_0 to G_0.

(44) Ninety-six per cent of the helium stars brighter than the sixth magnitude in the region galactic longitude 216° to 360°, latitude ±30°, belong to a single group.

(45) From the group motion the individual parallaxes of 319 of these stars have been determined. The resulting luminosity curve for the B_0–B_5 stars is fairly satisfactory. That for the B_5–B_9 stars is less reliable.

(46) A special investigation indicates that the method used for the parallax determination of helium stars is applicable to the brighter A–K stars of the first stream.

(47) A method for the derivation of the mean parallax of a group of faint stars, based upon the luminosity curve and the apparent magnitudes of the group, has been formulated.

(48) An examination of all available evidence indicates strongly that, on the average, the fainter stars are redder than the brighter ones, and that, apparent magnitude and spectral lines being the same, the stars are redder the farther away they are.

(49) The relation of these phenomena to spectral distribution, absolute luminosity, space absorption, etc., is becoming clearer, but extensive investigations will be required to separate the contributing causes.

(50) 867 chromium and 1,092 vanadium lines have been classified as to their appearance and changes with temperature.

(51) The enhanced lines of the titanium furnace spectrum are not increased in intensity by the presence of a hydrogen atmosphere; on the contrary, with pressure as great as one atmosphere, the intensities are reduced.

(52) The inner vapor of a powerful condensed spark produces dissymmetries of spectrum lines giving apparent displacements toward the red; the lines of the outer vapor coincide with the arc lines.

(53) Comparisons between the center and negative pole of the iron arc have been made for 1,600 lines. For 1,300 of these the wave-lengths are independent of the distance from the pole and the current strength.

(54) For 250 lines the wave-lengths at the negative pole exceed those at the center by 0.015 Å or more; for 50 lines they are less at the pole.

(55) The differences vary with the current, a change from 5 to 7 amperes giving measurable shifts for lines of negative displacement.

(56) The displacements are indirectly related to pressure shifts; provisionally, they are attributed to changes in density.

(57) Because of these circumstances, the wave-lengths of the questionable lines among the tertiary standards and the international secondaries are being redetermined under standard conditions.

(58) Measures of the Zeeman separation of 769 iron, 903 chromium, and 643 vanadium lines have been made from plates taken usually with field-strengths of about 30,000 gausses.

(59) Three series of determinations of e/m give a mean value of 1.761, with an uncertainty of 2 units in the third decimal.

STAFF.

In addition to his general duties, the Director has devoted special attention during the year to investigations of solar magnetic and electric phenomena, including a preliminary attempt, in conjunction with Mr. Babcock, to detect the Stark effect in sun-spots and other regions of the solar atmosphere. Dr. Walter S. Adams has continued his duties as Assistant Director and head of the department of stellar spectroscopy, and has carried on extensive studies of stellar spectra and the spectrum of the chromosphere. Professor Frederick H. Seares, in addition to his services as superintendent of the Computing Division and editor of the Observatory publications, has continued and extended his researches in stellar photometry and his work on the general magnetic field of the sun. Dr. Arthur S. King, superintendent of the physical laboratory, has devoted most of his time to the study of furnace, arc, and spark spectra. Dr. Charles E. St. John has continued his investigations on standards of wave-length and the determination of levels, pressures, and velocities in the solar atmosphere. Mr. Harold D. Babcock has collaborated with Dr. St. John in the study of wave-length differences in various parts of the arc, pushed forward his studies of the Zeeman effect, with special reference to the determination of e/m, and taken part in various other investigations. Mr. Ferdinand Ellerman has taken many solar photographs of various kinds with the 150-foot tower telescope and continued his duties as

Observatory photographer. Daily photography of the sun with the Snow telescope has been carried on by Messrs. Ellerman, van Maanen, and Monk. Mr. F. G. Pease has continued his photographic and spectroscopic observations of nebulæ, star-clusters, Novæ and variable stars, in addition to his duties in charge of instrument design. Dr. Arnold Kohlschütter continued his stellar spectroscopic observations and the study of stellar spectra until called early in August to serve as a reserve in the German army. He was captured by the British at Gibraltar, and is detained there as a prisoner of war. Dr. Adriaan van Maanen has begun a photographic investigation of stellar parallaxes, assisted in the stellar spectroscopic observations, and measured the spectra showing the general magnetic field of the sun. Many of these spectra were taken by Mr. Monk, who has also assisted in the stellar spectroscopic observations. Dr. Harlow Shapley, who joined the staff in April 1914, has devoted most of his time to investigations in stellar photometry. Mr. R. S. Capon, of the University Observatory, Oxford, who joined the staff on July 25, 1914, is engaged in the measurement of solar magnetic field spectra and other observational and theoretical work.

Professor J. C. Kapteyn, Research Associate, arrived in Pasadena on July 21, and will remain in California until December. During the year he has completed an extensive investigation on the parallaxes of the brighter helium stars (Mount Wilson Contribution No. 82) and continued his studies on star streaming, light scattering in space, and other stellar problems. Professor Carl Störmer, who visited the Observatory as Research Associate in 1912, has extended his investigations on the electromagnetic theory of the hydrogen flocculi to the bipolar type. Professor Peter Paul Koch returned to Munich in September 1913, after completing his experiments on the application of the registering micro-photometer to the study of solar, stellar, and laboratory spectra. Dr. J. A. Anderson, whose duties at the Johns Hopkins University required his return to Baltimore in September 1913, cooperated with Mr. Jacomini in the work of completing and testing the machine for ruling gratings. Mr. P. J. van Rhyn, after finishing the observational part of his investigation on the color indices of stars, returned to Holland in May.

The Observatory has lost a faithful and efficient member in the person of Miss Evelyn Wilhoit, whose death on April 22 was deeply felt by all of her fellow-workers. Her loyalty and devotion will always be associated with the first decade of the Observatory's history.

Director C. G. Abbot, of the Smithsonian Astrophysical Observatory, carried on his studies of the solar constant and related problems on Mount Wilson during the periods September 1 to November 9, 1913, and May 25 to July 4, 1914, when he left for Australia. Since the last date the work has been continued by Mr. L. B. Aldrich.

INVESTIGATIONS IN PROGRESS.

SOLAR RESEARCH.

INSTRUMENTS.

The principal changes made during the year in the equipment for solar research include the provision of a 6-inch Warner & Swasey equatorial refractor, with an Evershed spectroscope by Hilger, to be used mainly in finding eruptions and other changing phenomena for photographic observation with the Snow and tower telescopes; the addition of an outer tower and dome, and the improvement of the spectrograph and spectroheliograph of the 60-foot tower telescope; and the construction of the Koch registering micro-photometer, now nearly completed, which will also be used in connection with the stellar and laboratory work.

The 60-foot tower telescope was originally built as cheaply as possible, in view of the fact that so radical a departure from existing designs might fail to justify itself in practice. Its manifest advantages over the Snow telescope, both in definition of the solar image and performance of the underground spectrograph, soon led to the construction of the 150-foot tower telescope, which is still more efficient. It then became desirable to provide an outer tower, dome, and vertical tube for the 60-foot tower telescope, as the cœlostat and other instruments were insufficiently protected from the weather. The opportunity was also utilized to make some needed improvements in the quick and slow motions of the cœlostat and to provide the spectrograph with a Fabry-Perot interferometer, for use in Mr. St. John's investigations on the pressure and motion of the gases of the solar atmosphere. The temporary building at the foot of the tower has been replaced by a concrete structure, enlarged sufficiently to contain equipment needed in vacuum work with both arc and spark, including a device for producing simultaneous exposures on the solar and comparison spectra. With these improvements, which will make the 60-foot tower telescope completely fire-proof, it is expected that this instrument can be used for many classes of work, thus leaving the 150-foot tower telescope free for studies of the general magnetic field and the various other researches which demand a large solar image and the highest possible dispersion. As the new spot cycle opens, the pressure upon the time of the three solar telescopes is becoming so great that such relief will be very advantageous.

The almost unprecedented rains of last winter forced the walls of the 75-foot spectrograph well, in spite of their heavy covering of waterproofing material. This led to serious dampness near the bottom, which threatened to interrupt the work. Fortunately the difficulty has been removed by the installation of an electrically driven exhaust fan, which removes the air from the well, and causes a downward flow from with-

out. This is so gradual that no appreciable change in the admirable constancy of temperature has been caused, while the exposure times have been reduced practically one-half by the removal of the moisture.

DIRECT PHOTOGRAPHY OF THE SUN.

During the year ending August 31, 1914, 241 direct photographs of the sun were obtained with the Snow telescope. Few spots were recorded in the autumn and winter, but the advent of a new cycle of activity is now plainly apparent.

WORK WITH THE 5-FOOT SPECTROHELIOGRAPH.

952 photographs have been made with the 5-foot spectroheliograph, using $H\alpha$ and K_2 for the disk and for the prominences at the limb. As usual, these plates have furnished material for the measurement of the areas of the calcium flocculi and prominences by Miss Smith, and for various studies of spots and flocculi in connection with other phases of solar research.

GENERAL MAGNETIC FIELD OF THE SUN.

Our knowledge of the general magnetic field of the sun is based upon line displacements so minute as to fall well within the ordinary limits of error of spectroscopic measurements. A very conservative attitude is thus demanded, and no effort should be spared to verify the reality of the effect, which sometimes fails to appear in the measures of skilled observers. Most of the measures used in our investigations have been made by Mr. van Maanen with a parallel plate micrometer, but three other observers have also detected the opposite sign of the displacements in the northern and southern hemispheres with a measuring machine of the ordinary type. Mr. Capon, using a parallel plate micrometer, has also obtained results in good agreement with those of Mr. van Maanen. Finally, a series of measures on curves made by Professor Koch with his registering micro-photometer, which eliminates all possibility of personal equation, agree closely with Mr. van Maanen's measures of the same plates. The large Koch machine just completed in our instrument shop will serve for further work of this nature, and especially for the elimination of absolute errors due to personal equation.

During the year 2,178 photographs of spectra for the study of the sun's general field have been taken with the 150-foot tower telescope and 75-foot spectrograph by Mr. Ellerman and Mr. Monk. The earlier photographs, many of which were made at irregular intervals because of broken weather and other interruptions, were designed mainly for the detection of new lines showing Zeeman displacements, the determination of field strengths for lines representing different levels in the solar atmosphere, and the selection of lines suitable for use in a campaign planned for the exact location of the sun's magnetic poles and the

determination of the corresponding period of rotation. This campaign was begun in June, after the close of the rainy season, and continued throughout four solar rotations until September, with only an occasional interruption in the entire period. The resulting measures, which can not be completed before next year, will thus be very uniformly distributed in longitude. Moreover, preliminary observations have shown that occasional sun-spots which appeared during this time will require the rejection of very few plates.

Twenty-five lines have now been found to give displacements of the same character: positive in the northern hemisphere, negative in the southern, varying in magnitude from zero at the equator to a maximum value near latitude 45°. In every case, therefore, the existence of elliptical polarization attributable to the Zeeman effect is clearly indicated.

The elements represented are iron (10 lines), chromium (8), nickel (4), vanadium (2), unidentified (1). The weakest lines in the list are of intensity 0; the strongest is the wide sun-spot triplet Fe 6173.553, intensity 5. Thus the displacements due to the general field appear to be confined to the lower levels of the solar atmosphere, in harmony with our earliest results.

As the levels corresponding to these lines can be found from eclipse data, it should be possible to plot field-strengths as a function of level. We have recently discovered, however, that the observed displacements depend in some way upon the intensity and character of a line, so that an obscure source of error must be eliminated before the change of field strength with level can be determined.

The hypothesis of local whirls, in which the innumerable pores scattered over the sun are supposed to act like sun-spots, thus giving rise to the general magnetic field, was briefly mentioned in Mount Wilson Contribution No. 71. While this hypothesis might be able to account for certain of the observed phenomena, the weak points named in the above paper have been accentuated by the results given below, which show that sun-spots are apparently not of the same polarity throughout the northern hemisphere or the southern. If the pores follow the same rule, their polarity in low and high latitudes would presumably be opposite, and the observed Zeeman displacements could not be accounted for on the local whirl hypothesis.

THE POLARITY OF SUN-SPOTS.

The magnetic polarity of a sun-spot is easily ascertained by determining whether the red or the violet edge of a widened line is transmitted by a Nicol prism and quarter-wave plate. In our earlier work it was found that spots of opposite polarity occurred in the same hemisphere, and this result was confirmed by Evershed's and St. John's observations of radial motion. The reasonable expectation that the

sun-spot vortex would be found to have opposite directions of rotation in the northern and southern hemispheres was therefore not fulfilled.

The difficulty has now been cleared up by the necessary recognition of the characteristics of bipolar spots, first detected on Mount Wilson in 1909. It has long been known that sun-spots frequently occur in pairs, often accompanied by numerous minor companions. The discovery that the two principal members of such groups are of opposite polarity suggested the existence of a physical connection between them. It is important to note that even in the absence of one member of the group, calcium and hydrogen flocculi may occupy its place. The characteristic structure of the $H\alpha$ flocculi may even suggest the existence of a magnetic field, such as the second spot would produce if present.

It will suffice here, without entering into a discussion of such groups, to note that whenever the necessary criteria exist every spot should be classified as the preceding or following member of a bipolar group. Adopting this plan, and separating the spots whose polarities were observed before and after the recent sun-spot minimum into two groups, we have the following results:

Hemisphere.	Old cycle.		New cycle.	
	Preceding spots.	Following spots.	Preceding spots.	Following spots.
	V R	*V R*	*V R*	*V R*
Northern................	5 0	0 1	1 6	5 0
Southern................	2 15	7 0	5 0	0 2

Thus in the old cycle, 5 preceding spots in the northern hemisphere were characterized by the violet component of the Zeeman triplet, while one following spot showed the red component. In the southern hemisphere the polarities, with two exceptions, were reversed, 15 preceding spots showing the red component, while the violet component appeared in the case of 7 following spots.

After the minimum, we find for the new cycle the same rule of opposite polarity for the preceding (or following) spots in the northern and southern hemispheres, but, quite unexpectedly, the polarities in a given hemisphere are now reversed. It is too early to explain this remarkable change, but probably the polarity is determined by the latitude. In accordance with the well-known law, the late spots of the old cycle occur in low latitudes, while the advent of the new cycle is indicated by the appearance of high-latitude spots. As the two groups here in question are thus distinguished by a marked difference in latitude, the simplest explanation of the anomaly lies in assuming the

existence of high and low latitude zones in each hemisphere, distinguished by the presence of spots of opposite polarity. It remains for future observations to test this view and to reveal what happens in the zone of intermediate latitude.

SUN-SPOT SPECTRA.

The revival of solar activity, and the appearance of large sun-spots, have made possible the first application of the 150-foot tower telescope and 75-foot spectrograph to a study of spot spectra. The large size of the solar image and the high dispersion of the spectrograph are giving results decidedly superior to those obtained with the 60-foot tower telescope. The resolution of Zeeman spot doublets into quadruplets, and other beautiful magnetic phenomena revealed with the aid of a compound quarter-wave plate, afford ample evidence of the advantages of this combination, which is equally striking in the study of radial motions and other sun-spot phenomena.

THE STARK EFFECT.

The discovery by Stark that an electric field produces resolution of spectrum lines resembling the Zeeman effect, suggests new possibilities in solar research. The absence of circular polarization in the longitudinal Stark effect is a most valuable criterion, which leaves no doubt as to the validity of our conclusions regarding magnetic fields in sun-spots and the general magnetic field of the sun. But while the chief phenomena of spot spectra are undoubtedly of magnetic origin, it was conceivable that certain anomalies caused by an electric field might also be present. A study of our photographs, made soon after Stark's first announcement of his discovery in *Nature*, revealed no evidence of the Stark effect. But the possible influence of electric fields on spot spectra can not be finally determined until more solar and laboratory results are available.

The widening of the solar lines near the limb raises the question whether the Stark effect may be involved, on the probable assumption that the electric field of the sun is radial. If so, the edges of the hydrogen lines should be plane-polarized. Preliminary tests made on Mount Wilson some years ago showed no evidence of such an effect, and leave no doubt that the chief cause of the widening is not to be ascribed to an electric field. Recent photographic observations, made in the third order of the 75-foot spectrograph by Mr. Hale and Mr. Babcock, now demonstrate that if any Stark effect exists it is extremely small. A compound half-wave plate, used with Nicol, permitted tests of great delicacy to be made. Some of these seemed to indicate traces of plane polarization at the edges of the lines, but the observed widening was so slight that the evidence could not be accepted as in any way

conclusive. The plates are now being measured with the Koch registering micro-photometer, which should give much more reliable results than visual measures. It is evident that even if no positive effect can be found, it will at least be possible to set an upper limit to the intensity of the electrical field at this level in the solar atmosphere. The observations will also be extended on the laboratory side, and applied to various promising regions of the solar atmosphere.

THE FLASH SPECTRUM WITHOUT AN ECLIPSE.

During the year an investigation was completed by Mr. Adams and Miss Burwell of the chromospheric spectrum in the region λ 4800 to λ 6600, based on photographs taken with the 60-foot tower telescope. A total of 1,193 bright lines have been observed in the region λ 4800 to λ 6600. Of these the wave-lengths of 1,024 have been measured, and the remaining 169 have been noted as pairs of bright fringes on the sides of absorption lines.

A comparison with Mitchell's eclipse spectrum results indicates that the number of lines is somewhat greater on the tower telescope photographs. Between λ4800 and λ5880 Mitchell gives 901 lines, while the Mount Wilson negatives give 1,027. The average deviation of the wave-lengths of the measured bright lines from the corresponding dark lines of Rowland's table is, in the case of the Mount Wilson values, 0.012 Å; in the case of the eclipse values, 0.030 Å. For the purposes of this comparison only single lines, and not blends, have been included.

Double reversal is a universal characteristic of the stronger dark lines of the solar spectrum when seen in the chromosphere. The bright lines are symmetrical with reference to the dark central line in essentially every case, and the two components in a great majority of cases have equal intensities.

A very low level in the solar atmosphere for the point of observation is indicated: (*a*) by the double reversal of the stronger Fraunhofer lines; (*b*) by the great number of very faint Fraunhofer lines, which appear bright in the chromosphere; (*c*) by the great strength of the carbon fluting at λ 5165.

The effect of this low level as compared with that of the eclipse observations is seen in the differences among the lines observed. Most of the strong Fraunhofer lines appear as single bright lines on the eclipse photographs. On the tower telescope photographs some of these lines appear only as dark lines, and the others are seen as double reversals, or as dark lines with bright fringes. These lines belong to a comparatively high level in the solar atmosphere. On the other hand, the tower telescope photographs show hundreds of bright lines due to very faint Fraunhofer lines, which are at a low level in the reversing layer.

The lines of La, Ce, and other elements of high atomic weight appear as very strong bright lines in the chromospheric spectrum. At the

same time lines of equal intensity as dark lines in the solar spectrum of such elements as Fe and Ni remain as dark lines, or are faintly doubly reversed. It seems necessary to conclude that the level of the elements of high atomic weight is decidedly below that of Fe and elements of similar behavior, even for lines of the same solar intensity, an inference amply confirmed on other grounds by the work of St. John, Adams, and others. The hypothesis put forward by St. John that the great intensity in the flash spectrum of the lines of elements of high atomic weight is due to the intense radiation of thin strata of gases at a very high temperature at the base of the reversing layer seems to be in excellent accord with the observations.

The double reversals of the enhanced lines are considerably narrower on the average than those of arc lines of the same solar intensity.

There is no certain indication of any systematic displacement of the bright lines relative to the dark lines of the spectrum of the sun's limb. If any such displacement exists it can not exceed a very few thousandths of an Ångstrom unit. It would appear necessary, therefore, if anomalous dispersion is assumed to exist in the sun, to conclude that the regular radial density gradient is completely balanced by irregular gradients of opposite direction, a conclusion opposed to many facts of observation.

As a by-product of the chromospheric investigation, some remarkable differences have been observed in the dark-line spectrum of the sun's extreme limb as compared with that of the center of the sun, which are so great as to render the spectrum unrecognizable in certain regions. The two most important features are:

(*a*) The great weakening or strengthening of some of the solar lines, and in a few cases the appearance of new lines. Among other cases attention may be called to the following:

Line.	Intensity.	
	Sun.	Limb.
5034.737	....	2
5037.458	0000 0000	2
5037.885	000	2
5042.200	0000	2
5149.013	000	1–2

(*b*) The presence of what appears to be a band spectrum in the region between λ 5050 and λ 5150. This may be identical with the spectrum of magnesium hydride observed by Fowler in the spectrum of sun-spots.

DISTRIBUTION OF ELEMENTS IN THE SOLAR ATMOSPHERE FROM ECLIPSE DATA.

A discussion, by Mr. St. John, of Mitchell's eclipse data from the standpoint suggested by his investigation of radial motion in sun-spots, confirms Mr. St. John's previous conclusions in several points. The lengths of arc in the flash spectrum indicate the highest levels for the H and K lines of calcium, followed by the hydrogen lines, while the heavy elements and carbon appear only in the lower portion of the solar atmosphere, in complete accordance with the radial-motion results.

The radial displacements of the iron lines, arranged according to solar intensities, furnish a scale of relative levels which is confirmed by the eclipse data, thus supplying the means of translating relative into absolute elevations. A statistical study of 666 flash lines shows that the elevations are less for lines in the red than for lines of the same solar intensity and of shorter wave-lengths, in harmony with the radial-motion results.

Weakness of solar lines or lowness of level in the solar atmosphere is associated with strong flash intensities relative to the Fraunhofer lines, of which the flash lines are the reversals. A seeming disagreement regarding carbon, lanthanum, and cerium, placed by Mitchell above iron because of their longer arcs, finds an explanation in the increased flash intensity of these low-level lines due to the higher temperature at the lower level. This causes their arcs to be traced to a greater distance than in the case of iron lines of the same flash intensity and accounts for three-fourths of the excess.

The heights reached by enhanced lines are greater than for unenhanced lines of the same solar intensity, in agreement with the adopted interpretation of radial displacements. The discussion brought out the following additional facts relative to enhanced lines in the chromosphere: the intensity of enhanced lines relative to that of the solar lines increases with the intensity of the solar lines instead of decreasing as for unenhanced lines; the greater the heights given by the unenhanced lines, the greater the intensity relative to that of the solar line, which is opposite to the course for unenhanced lines; there seems to be no relation between the degree of enhancement in arc and spark and the heights in the chromosphere; an intensifying of the enhanced lines has been assumed to be brought about by the atmosphere of hydrogen obtaining in the sun, but a comparison of the enhancement of lines that occur in an atmosphere of hydrogen with the eclipse data shows no relation between the two phenomena; the behavior of the enhanced lines in the chromosphere appears to be in entire harmony with the enhancement of the spark lines that occur under reduction of pressure, an explanation suggested by Gale and Adams when discussing the enhancement of the spark lines of titanium under decreased pressure.

PRESSURE IN THE SOLAR ATMOSPHERE.

Mr. St. John's investigations on the relative wave-lengths of arc and solar lines, begun three years ago with the 60-foot tower telescope, have been continued to great advantage with the 75-foot spectrograph of the 150-foot tower. It soon appeared, however, that a detailed study of individual lines in various parts of the arc would be necessary before a satisfactory discussion of the measures could be undertaken, Some of the results of this work may be found in another part of this report. Pending its completion, it has seemed worth while to publish the data in hand, because of their bearing on Einstein's suggestion that the Fraunhofer lines may be shifted toward the red by the effect of solar gravitation, and because of Evershed's paper on this subject.

The lines, 163 in number, are distributed among the five pressure groups as follows:

Group.	No. of lines.	Mean solar interval.	Mean λ.	Sun-Arc. (Unit 0.001 Å)
a	32	4.9	4991	+ 5.9
b	51	5.4	4806	+ 3.1
c	13	5.2	4346	− 2.7
d	52	4.7	5326	− 7.6
e	16	4.9	5687	+18.0

The results for the groups are decidedly characteristic and clearly show that the Fraunhofer lines fall into the identical groups into which the arc lines are classified by pressure shift, suggesting an intimate relationship.

According to Freundlich, the magnitude of the Einstein displacement to the red, independent of element or class of line, is 0.009 or 0.010 Å for these wave-lengths. There is, however, no indication of a general displacement to the red of the order required; in fact, 40 per cent of the lines are displaced to the violet and 80 per cent of the displacements to the red are much under the magnitude predicted. According to the anomalous dispersion theory, as interpreted by Professor Julius, the Fraunhofer lines must be displaced to the red. The data are equally opposed to this theory.

Groups *a* and *b* contain the lines for which the precision of measurement is the highest. On the assumption that pressure in the solar atmosphere is alone effective in producing these displacements, they indicate an anomalous distribution of pressure, in which the greatest pressure is at the highest level. It is evident that pressure, though clearly involved, is not the only cause. Assuming that the displacements are due only to a downward motion and that pressure in the solar atmosphere does not differ greatly from zero, we have the other extreme

case. The indicated velocity is greatest at the highest level and falls to a minimum and rises again, as does the pressure on the previous assumption.

The graph of intensities and velocities shows a point of inflexion between intensities 4 and 5. This indicates that pressure begins to be effective at this level. By extending the uninflected course of the graph, it appears that the downward velocity dies away at about the level of intensity 3. Such an extrapolation is hazardous, but offers a means of separating the two effects. The conclusion is that the solar vapors are descending with a decreasing velocity which approaches zero at the level of lines of solar intensity 3, that the pressure does not differ greatly from zero above the level of lines of intensity 5, and that at the level of lines of intensity 4 it is approximately one terrestrial atmosphere and increases rapidly with depth.

Lines of groups *c* and *d* with positive pressure shifts are displaced to the violet under the decreased pressure in the solar atmosphere, as the observations show. Lines of group *e*, with a negative pressure shift, are displaced to the red by the decrease of pressure.

Added evidence that the pressure in the solar atmosphere is approximately zero at the level of lines of intensity 5 is given by obtaining the velocities required to produce the observed effects in the several groups whose average intensities are all nearly 5. These are in very close agreement for all groups. No estimation of the pressure at lower levels can yet be made, but the sharpness in the solar spectrum of diffuse arc lines shows that it is moderate. The observations will be extended to weaker lines as rapidly as possible. The great mass of the vapors forming the solar atmosphere is found within a very thin layer in which the pressure gradient is high. The observations appear to support the growing view that the sharp boundary of the sun may be explained without the assumption of a cloudy photosphere. The known downward drift of the rare high-level vapors, now found to be shared by those at lower levels, is analogous to the slow settling down of volcanic dust in the terrestrial atmosphere. The upward currents are narrowly localized and find their origin probably in the prominences.

This investigation will be continued with the reconstructed 60-foot tower telescope, using arc and spark *in vacuo* for comparison spectra, apparatus for simultaneous exposure of solar and comparison sources, and a Fabry-Perot interferometer with fused quartz plates, in invar mounting.

SOLAR ROTATION.

Observations of the solar rotation are being made by Mr. Adams and Mr. St. John with the 150-foot tower telescope and 75-foot spectrograph. A distinct gain in precision over previous work is hoped for, because of the better quality of the grating and the enlarged solar image,

which should reduce the effect of accidental errors in determining the location of the points observed. The first order, scale 1 mm. = 0.7 Å, is used for the major part of the observations, but for some special purposes the second order, scale 1 mm. = 0.35 Å, is employed. The regions include that between λ 4220 and λ 4280, covered by all observers in common, and the special region λ 5100 to λ 5300, assigned to this Observatory by the Committee of the International Union for Cooperation in Solar Research. Observations are made at latitudes 0°, 30°, 60°, 75°, 80°, 85°, and 90°, with particular emphasis upon the higher latitudes.

INVESTIGATIONS OF STARS AND NEBULÆ.

OBSERVING CONDITIONS.

During the year ending August 31, 1914, the 60-inch reflector was in operation 188 entire nights and during parts of 83 nights, while on 94 nights no observations could be made. The instrument was in use 2,215 hours out of a total of 3,600 hours of darkness, or 61.5 per cent of the total night-time. There were 1,315 hours lost because of weather conditions, and 70 hours on account of silvering the 60-inch mirror and repairs to the instrument. The statistics for each month are given in the following table, prepared by Mr. Hoge, night assistant:

Date.	Hours darkness.	Hours clear.	Hours cloudy.	Hours lost silvering and repairs.	Hours exposure time.	No. of photographs.	Observations.		
							All night.	Part of night.	None.
1913.									
September....	295	248	47	..	182	181	24	3	3
October......	336	262	74	..	178	211	20	7	4
November....	329	174	155	..	120	145	12	7	11
December....	346	162	184	..	127	133	8	11	12
1914.									
January......	346	129	217	..	87	127	9	6	16
February.....	308	162	146	14	117	133	11	8	9
March.......	324	186	138	2	144	121	14	8	9
April........	286	115	171	..	94	96	8	7	15
May.........	266	178	88	8	117	131	13	13	5
June.........	238	198	40	..	142	154	23	4	3
July.........	255	208	47	10	141	283	22	5	4
August......	271	263	8	36	158	260	24	4	3
Totals...	3,600	2,285	1,315	70	1,607	1,975	188	83	94

The total exposure time for the year is 1,607 hours, which is 70 per cent of the working time and 45 per cent of the hours of darkness. The exposures on individual plates range from 1 minute to 30 hours, the average being 49 minutes.

As appears from the above table, the weather conditions during the winter months were unusually poor, while those of summer have been

very good. In June and July, 37 consecutive full nights were secured, and in August there were but 8 hours of interruption by clouds. A record of the seeing, on a scale of 1 to 5 (the latter being perfect), is shown herewith, together with the wind-record from Mr. Hoge's observations:

Seeing.		Wind.	
<1 to 1	57 nights.	Very high	4 nights.
1 to 2	70	High	21
2 to 3	118	Brisk	40
3 to 4+	30	Moderate	48
		Light	121
		Calm	114

The wind percentages, which are somewhat more favorable than those of the preceding year, are: high, 7; brisk and moderate, 25; light to calm, 68.

The average change of temperature in the dome between the time of opening in the late afternoon and of closing in the morning was 5°.9 C. The highest temperature recorded was 30°.4 C. on August 13, while the lowest was −4°.0 C. on January 27.

DIRECT PHOTOGRAPHY.

During the year Mr. Pease obtained the following photographs at the principal focus of the 60-inch reflector:

Spiral nebulæ	N. G. C. 972, 4567–8, 5740, 7217.
Spindle nebulæ	N. G. C. 955, 4388, 4402, 4425, 4564, 5476.
Nebulæ with bright center in nebulous mass with no detail	N. G. C. 4374, 4387, 4406.
Irregular nebulæ	N. G. C. 1555, 1579, 2264.
Star clusters	Additional plates of M 13 and M 15 for counting; N. G. C. 6760.

Five plates so far have been obtained of the region of N. G. C. 1555, Hind's Variable Nebula in Taurus. No change can be detected not attributable to differences in the quality of the plates.

Two plates have been taken of N. G. C. 6760, described by recent observers as a variable nebula. The photograph of 1½ hours' exposure on a Seed 27 plate shows it to be an irregular circular cluster 7 minutes in diameter containing about 1200 stars ranging approximately from 16.5 to 19.5 photographic magnitude, superimposed on a background whose average density is 15 stars per square minute. No trace of nebulosity is found.

Miss Van Deusen has counted the stars on photographs of a number of clusters made by Mr. Pease. Owing to conditions of seeing, distance from the zenith, and the difference in plate emulsions, it is often the case that a shorter exposure will contain more stars than a longer one, but

as more plates are used the averages fall into a series progressively increasing with length of exposure.

For counting, a reseau having 44 by 56 squares was used, each square being 30 seconds on a side. The negative was observed directly under a power of 12. The number in each square was noted on squared paper and the vertical and horizontal columns were added and plotted. The N.–S. (horizontal columns) curve in every case is more pointed and has a higher maximum than does the E.–W. curve, though the areas in each case are identical. From the series of short-exposure curves of the same cluster in which stars are counted clear to the center, a general curve is being deduced for each cluster that may be applied to those plates in which the center is burned out and the total number of stars thus obtained. All the photographs are on Seed 23 plates.

The following results for Messier 13 are typical and indicate the character of the results with increasing exposure time:

Exposure.	No. of plates.	No. of counts.	No. of stars.	Remarks.
mins.				
1	2	4	955	
3	1	2	1,693	
6	4	8	4,747	
15	2	5	5,781	
22	1	4	14,683	
37.5	1	4	16,436	Except 2 sq. min. in center.
94	1	2	21,788	Except 6 sq. min. in center.
300	1	2	22,159	Except 16 sq. min. in center.

DIRECT DETERMINATION OF PARALLAXES.

For the parallax work, 282 plates have been taken by Mr. van Maanan with the 80-foot focus combination of the 60-inch reflector. Most of the plates were given two exposures to the same field, and on six of these the distances of the images were measured to obtain an idea of the accuracy attainable in the final results. The probable error of a distance measured in two positions of the plate is $\pm 0''.030$, when all the stars on the plate are included, and $0''.023$ when only those near the center are used. These figures indicate a very satisfactory degree of precision, but some months must elapse before a wholly reliable opinion can be expressed as to the accuracy. At present provisional parallaxes are available for two stars:

Boss 6097 $\pi = +0''.094 \pm 0''.010$ (4 plates, 2 exposures each).
5519 $\pi = -0.039 \pm 0.020$ (6 plates, 2 exposures each).

STELLAR PHOTOMETRY.

The observational part of the investigations in stellar photometry by Mr. Seares and Mr. Shapley includes 614 photographs, all made with the 60-inch reflector and distributed as follows:

RS Boötis	91	N. G. C. 1647	11
XZ Cygni	44	N. P., faint stars	12
XX Cygni	58	N. P., bright stars	229
S Cygni	18	Selected Areas	88
X Cephei	19	Miscellaneous	16
R Piscium	28		

Magnitudes of Polar Stars.

The investigation of the magnitudes of stars near the Pole, including those of the North Polar Sequence, is now nearing completion. The photographic scale has been established from the second to the twentieth magnitude, and results for about 600 stars have been derived. From the eleventh magnitude downward, two series of plates, taken mostly with diaphragms and screens, were available; one with a maximum exposure of 11^m and a limiting magnitude of 17.8, the other with exposures ranging from 30^m to 5^h, and a limiting magnitude of about 20.1 (International Scale). About 3,000 magnitudes were obtained for the 66 stars appearing on both series. The numerous individual values greatly facilitated the discussion of the results for systematic errors and permitted, for the first time, a satisfactory determination of the distance correction for very faint stars and an evaluation of the irregularities affecting the glass scale used for the measurement of the images. Each series of plates gave several independent determinations of the magnitude scale, and the agreement of the mean scales for long and short exposure is indicated by the second column of the accompanying table.

Mt. Wilson Phot. Mag.	Long exposure *minus* short exposure.	Mt. Wilson *minus* Harvard.
10.6	+0.02 mag.	−0.01 mag.
11.7	+0.01	−0.05
12.8	−0.01	+0.02
13.4	0.00	+0.02
14.0	+0.02	+0.03
14.3	−0.03	+0.03
14.8	0.00	−0.03
15.5	+0.03	−0.05
16.8	+0.02	−0.17
17.9	......	−0.39
18.5	......	−0.53
19.0	......	−0.84
19.5	......	−1.01

A comparison of the mean scale for the two series with that of Harvard Circular No. 170 is given in the last column. The result for the

interval 10.5–15.5 is substantially that previously reported, and the divergence for the faint stars indicated by the preliminary reduction appears to be confirmed.

In examining the table, it is to be noted that the Mt. Wilson magnitudes and the differences Mt. Wilson − Harvard require the addition of a constant, whose provisional value is +0.37 mag., to reduce them to the international zero-point.

The revision of the zero-point constant and the magnitudes of some of the brighter stars is now in progress and, when completed, the investigation of the photographic scale can be brought to a conclusion.

In the meantime a satisfactory determination of the photovisual scale has been made for magnitudes 2 to 17.5 by means of isochromatic plates and a yellow filter. The results for the lower 6 magnitudes are complete, and a preliminary connection with the stars of the sixth magnitude has been made for the determination of the zero-point. This and the magnitudes of the bright stars require revision, but the reductions are sufficiently advanced to indicate a fairly satisfactory agreement with the Harvard visual scale of the Polar Sequence.

Important evidence bearing upon the relation of the photographic and photovisual scales to each other is described below in connection with the color results found for N. G. C. 1647.

The Color of the Faint Stars.

The extension of the photographic and photovisual scales to very faint stars gives at once values for the color of these objects. The dependence of color index (photographic *minus* visual magnitude) upon spectral type is well known; its behavior with increasing magnitude may be studied by comparing the photographic and photovisual scales. Such a comparison has been made for the Pole and for the regions of S Cygni and N. G. C. 1647, the scales for the last two regions being established by comparisons with the Pole. In each case it was found that the color index of the whitest stars gradually increases with increasing magnitude. At the seventeenth magnitude the minimum index is about +0.6 mag. Since the corresponding value for the bright B_0 stars is −0.4, the increase is about 1 mag.

The interpretation of this result is uncertain. It may mean a preponderance of later type spectra among the fainter stars; it may be the consequence of absolute luminosity, for the fainter stars are less luminous, on the average, than the brighter objects; or it may be the effect of a scattering of light in its passage through space.

If the color indices are to be accepted as an indication of spectral type, the conclusion would be that there is a gradually increasing suppression of the earlier types with increasing magnitude, and hence also with increasing distance, for the majority of the faint stars are faint because of distance.

The assumption that the increase in color is a consequence of absolute luminosity must be considered in connection with the spectroscopic results discussed elsewhere. These show that stars of high luminosity (mostly of great size) are redder than those absolutely fainter, but that the effect is a function of spectral type and probably inappreciable for first-type stars. The color indices, however, would indicate that the absolutely faint stars are the redder. To reconcile these results we must suppose, first, that among the faint stars there are few or none of early type, for, as just stated, the color of these is apparently independent of their luminosity and should be the same for all magnitudes; second, that the relatively high color of the stars of small luminosity is only indirectly a luminosity effect and probably is to be explained on the basis of spectrum. The spectroscopic results make it unlikely that abnormally high color for any given spectrum is associated with low luminosity, while there is a very definite relation between small luminosity and advanced spectrum. This, however, merely throws us back upon the previous explanation, which attributes the increase in the minimum color index to a very special distribution of spectral types. Upon the color effect thus produced is superimposed that due to luminosity in the sense revealed by the spectroscopic observations. The completeness with which the earlier spectral types would have to be excluded from the faint stars in order to make such an explanation tenable is indicated by the fact that for several hundred stars fainter than the eleventh magnitude no single value of the color index falls appreciably below the sharply defined limit fixed by the smaller values.

The decision between such an explanation and that of the third possibility—space absorption—is at present a question of probabilities. Some light might be thrown upon the matter by a precise determination of the behavior with increasing magnitude of the mean or the maximum color index, but the data at present available are insufficient for this purpose.

Finally, it should be remarked that a phenomenon pointed out by Hertzsprung must also be involved, but it seems unlikely that this affords a complete explanation.

Considered by themselves, the color results for N. G. C. 1647 afford a valuable control upon the relation of the magnitude scales to each other. The colors of a large number of stars in this cluster have also been determined by Professor Hertzsprung by means of a large objective grating. The transformation of his effective wave-lengths into color indices gives results agreeing very closely with those found directly from the photographic and photovisual magnitudes. Fifty-two stars between magnitudes 11 and 14.5 have, according to the effective wave-lengths, a mean index of +0.46 mag. That found from the magnitudes is +0.47 mag. The agreement is closer than was anticipated, for the

zero-points of the magnitude scales for the polar stars are provisional, and their transfer to the cluster introduces into the color indices a further uncertainty of 0.04 mag.

Color Variation of the Cluster-Type Variable RS Boötis.

Eighty-five ordinary and isochromatic plates, alternately exposed on July 16, 17, and 18, establish with a good degree of precision the photographic and photovisual light-curves of the cluster-type variable RS Boötis (period 9^h 03^m). The photographic amplitude is 1.5 mags., the photovisual about 1 mag. A clearly marked change in color is thus revealed. The zero-points of the magnitude scales are yet to be determined, so that the absolute values of the color index can not now be given. The change in the color index of 0.4 mag. agrees satisfactorily with Mr. Pease's observations of the change in the spectrum. His limiting values are B_8 at maximum and F_0 at minimum. The corresponding color indices on Parkhurst's scale would be -0.10 and $+0.40$. The epochs of maxima for the two curves agree within the uncertainty of the determination.

Magnitudes for the Selected Areas.

Considerable progress has been made in the determination of standard magnitudes for the Selected Areas, as described in the previous report, though less than could be expected normally. Unsatisfactory atmospheric conditions have interfered with the observational program, and the reductions have been delayed in order that the information concerning systematic errors afforded by the final discussion of the results for the polar stars might be available. The completion of the latter investigation now makes it possible to take up actively the reductions for the Selected Areas.

STELLAR SPECTROSCOPY.

The stellar spectroscopic work of the past year has included observations of the spectra of stars selected from the following lists:

1. Stars of types F to M_0 of very small proper motion. Their spectra have been used for radial-velocity determinations, for investigations of the absorption of light in space, and for a study of spectral differences between stars of small and stars of great absolute brightness.
2. Stars with measured parallaxes and in general of very large proper motion. These stars have been under investigation for the past four years, and the amount of observational material regarding them has now reached considerable proportions. Their characteristics are the precise opposite of those of the stars in list 1, these stars being comparatively near to the earth, of small absolute brightness, and probably of small mass and size.
3. Stars suspected of belonging to the Perseus group.

4. Stars suspected of belonging to the Taurus group.

5. Miscellaneous lists including: A-type stars of especially small proper motion; M-type stars of large and of small proper motion, the spectra of which have been obtained for comparison with one another; the brighter stars in Kapteyn's Selected Areas; and a few stars of especial individual interest, such as Nova Geminorum No. 2, Kruger 60, and some other stars of very small absolute luminosity.

The total number of photographs obtained during the year is 980, distributed as follows:

Small proper-motion stars, types A to Mc	620
Parallax and large proper-motion stars	237
Perseus group	8
Taurus group	18
Miscellaneous A and B type stars	22
Absorption of light in space photographs	34
Miscellaneous	41

By far the larger part of the photographs have been taken with the 46-cm. camera and one prism. This low dispersion is necessary in the case of the majority of the parallax stars on account of their faintness, and since the spectra of the small proper-motion stars are compared with those of the parallax stars in several of the investigations, it has seemed best to obtain both spectra on the same scale. Photographs with the 102-cm. camera have supplemented the smaller-scale negatives in the case of some of the brighter stars. A few experiments have been made recently with a 39° prism and the 46-cm. camera on some stars in our lists fainter than the ninth magnitude, with results which will probably warrant the use of this arrangement where higher dispersion can not be employed.

The results of the stellar spectroscopic work during the year may be considered under three heads: first, radial velocity; second, absorption of light in space; third, spectral criteria of absolute magnitude.

Radial Velocities.

The total number of stars with radial velocities determined from three or more observations so far obtained is as follows:

A, B, and Oe stars	289
Stars with measured parallaxes	147
Small proper-motion stars, F to Mc	96
Miscellaneous	13
Spectroscopic binaries	115

During the year the results have been published for 100 of the parallax stars. These are among those nearest to the earth and for the most part are of small intrinsic brightness and probably of small mass as well. Their velocities accordingly are of especial interest. Among the results found are the following:

Twenty stars have radial velocities exceeding 50 km. after being corrected for the sun's motion in space. Five of these velocities are

positive and 15 are negative. Six stars show velocities of over 100 km., the largest of these, that of Lalande 1966, being −319 km. Two stars of type A show velocities exceeding 100 km. These are the first A-type stars found to have very high constant velocities. Several pairs of optically double stars are shown by their radial velocities almost certainly to be physically connected.

Recent observations of the star O. Arg. S. 14320, magnitude 9.2, indicate that its motion in space must be extraordinarily rapid. The star has a carefully determined parallax of $+0\overset{''}{.}035$ and a proper motion of $3\overset{''}{.}76$ annually. Its radial velocity as determined approximately with the low-dispersion spectrograph is +290 km. This gives for its motion in space 577 km. per second. There is a second star of the same proper motion about 5′ distant from it. The spectrum of the star is G_2.

The number of spectroscopic binaries discovered during the year is not large, the proportion of binaries among the solar-type stars which have formed the principal part of the observing list being much less than among the A- and B-type stars observed in previous years. A peculiarly interesting binary is the parallax star Lalande 18397, magnitude 7.7. The spectra of both components are seen on the photographs of this star, and both appear to be of type K_0. The maximum difference of velocity so far observed between the two components is about 120 km.

Absorption of Light in Space.

One of the principal effects of the absorption of light in space should be a weakening of the violet light of the more distant stars relative to the red light, when we compare such stars with those which are nearer to us. The problem may be investigated in two ways: The fainter and the brighter stars in a given portion of the sky may be photographed with and without a visual color screen, and the difference of color between the bright and the faint stars may thus be determined; or the spectra of stars of the same spectral type, some of which are known to be near and others distant, may be compared with one another. Each method has its disadvantages. The color-screen method involves two assumptions: first, that the distribution of spectral types is the same among the bright and among the faint stars; second, that the faint stars are faint on account of distance. The disadvantages of the actual comparison of the spectra of the stars are that it can be applied only to comparatively bright stars, and that the accumulation of material is necessarily slow.

The most accurate comparison of the spectra of stars of the same type but of different distances may be made by obtaining their spectra on the same photographic plate. In this way the effect of differences of zenith distance and of variable transparency of the sky on the spectra is nearly eliminated. It is also necessary to obtain practical identity

in the spectra to be compared, and for this purpose it has not been found possible to depend on existing catalogues. The spectra have all been classified from our own photographs made for radial-velocity determinations.

The results of about 20 photographs of this kind taken during the year leave no doubt of a difference in the violet portion of the spectrum between near and distant stars; 14 of the spectra show the distant star to be much fainter in the violet region, while in the case of the other 6, of which 2 are of the A type, there is little or no difference. In no case is the nearer star relatively weak in the violet region.

In order to supplement these results with a larger amount of material, the radial-velocity photographs of the parallax stars and of the small proper-motion stars have also been used. Although these were taken at a great variety of zenith distances and on different nights, it seems probable that in forming two groups of results for considerable numbers of small and large proper-motion stars the errors from these sources should be very nearly the same in the two cases, and so not affect the comparison. The spectra of all of the stars used in this way were compared with a series of standard spectra at a number of points in the violet and in the red portions of the spectrum, estimations being made of their relative intensities. The standard spectra were then measured under a Hartmann micro-photometer and the results for all of the stars were reduced to densities. The values follow:

	No. of stars.	Average μ	Average type.	Density at λ 4220.	Density at λ 4955.
F_0–F_9	10	0ʺ.012	F_4	0.25	0.37
	23	0.66	F_6	0.32	0.37
G_0–G_4	8	0.009	G_3	0.22	0.41
	30	0.64	G_2	0.33	0.41
G_5–G_9	14	0.011	G_7	0.25	0.48
	22	0.64	G_7	0.40	0.48
K_0–K_4	24	0.011	K_3	0.16	0.44
	20	0.70	K_1	0.31	0.44

It is evident, from these results, that while the nearer stars are much stronger in the violet part of the spectrum than the more distant stars, the amount of this effect depends upon the spectral type, being twice as great for stars of types K_0–K_4 as for stars F_0–F_9. Since the average proper motions for the groups of small and large proper-motion stars are closely the same for the different types, we are obliged to conclude that the difference in the intensity of the violet part of the spectrum must be due largely to physical conditions in the stars themselves, the atmospheres of the stars of great intrinsic brightness absorbing and scattering the violet light more than those of the fainter stars.

SPECTRAL CRITERIA OF ABSOLUTE MAGNITUDE.

In the course of the comparison of the spectra of the large and the small proper-motion stars, two differences of a systematic character between these two kinds of stars have been observed in the line spectrum:

1. The hydrogen lines are abnormally strong in a considerable number of the small proper-motion stars. The effect is particularly striking in the case of several stars which show strongly the titanium bands characteristic of type M. The hydrogen lines in these stars normally should be comparatively weak, but actually are as strong as in type G_5 of the Harvard classification. In many other stars showing these bands the hydrogen lines are as strong as in normal K-type stars. Although by no means certain as yet, it seems probable that abnormal strength of the hydrogen lines will prove to be a characteristic feature of all stars of great absolute luminosity. Measures of the radial velocities given by the hydrogen lines are in sufficiently close agreement with those given by other lines to indicate that the excess absorption is mainly, if not wholly, due to the stellar atmospheres, and not to hydrogen gas in space.

2. Certain spectrum lines are weak in the large proper-motion stars and strong in the small proper-motion stars, and conversely. The most notable cases of lines strong in the large proper-motion or low-luminosity stars are four lines which are much strengthened in the spectra of sun-spots, and which probably are low-temperature lines. The most important case of a line strong in the high luminosity stars is the strontium line at λ 4216, which is exceedingly prominent in the spectrum of the chromosphere. The possibility of applying these results to the determination of absolute magnitudes has been investigated in the following way:

The spectral types of 162 stars were first determined accurately from a comparison of the intensity of the hydrogen lines with certain other lines in the spectrum, the differences of intensity being estimated on a definite scale, and this scale then reduced to the Harvard system by means of stars of known type. The 162 stars were divided into two groups—types F_8 to G_6, containing 71 stars, and types G_6 to K_9, containing 91 stars.

The absolute magnitudes of all of the stars were then computed, from the parallaxes where they were available and from the proper motions where they were lacking or very small. The means of the absolute magnitudes were then formed separately for the low and the high luminosity stars, and against these were plotted the differences of intensity of those lines which showed the greatest variation with absolute luminosity. Curves were drawn through the results and then each curve was applied to the case of the individual star. In other words, the absolute magnitude of the star was determined from the relative intensities of the selected-spectrum lines.

The values of the absolute luminosities obtained in this way proved to be in satisfactory agreement with those computed from parallax or proper motion. The average differences for the 71 F_8 to G_6 stars is about 1.6 magnitudes; for the 91 G_6 to K_9 stars slightly less than 1.5 magnitudes. It appears, therefore, that the use of spectral lines as criteria for the determination of absolute magnitude and parallax promises valuable results in this difficult field of investigation.

Spectra of Temporary Stars.

Spectra of the following temporary stars have been obtained during the year by Mr. Adams and Mr. Pease with the small spectrograph at the primary focus of the 60-inch reflector:

Nova Aurigæ	1891	Mag. 14
Nova Persei	1901	12.4
Nova Lacertæ	1910	12.5
Nova Geminorum No. 2	1912	10

Nova Geminorum No. 2 has also been photographed with the Cassegrain spectrograph. The exposures ranged from 2 to 16 hours. An examination of the spectra leads to the following conclusions:

The principal nebular lines at λ 4959 and λ 5007 have disappeared from the spectra of Nova Aurigæ and Nova Persei, but are still present in the other two stars. This observation is in agreement with that of Hartmann in 1907 on Nova Persei. The continuous spectrum is very strong in Nova Aurigæ and Nova Persei, less so in Nova Lacertæ, and of variable intensity in Nova Geminorum No. 2. The principal nebular line at λ 5007 is intensely strong in Nova Lacertæ, but the nebular line at λ 4364 usually ascribed to the same vibrating atom is very weak.

The disappearance of the chief nebular lines in the spectra of the older of these stars makes them identical with the spectra of some of the Wolf-Rayet stars. In view of this fact and the well-known agreement in distribution relative to the Milky Way of Novæ and Wolf-Rayet stars, it seems probable that at least a portion of the latter are temporary stars in the later stages of their history.

Since there is at present no hypothesis which accounts for the phenomena of a temporary star in a more satisfactory way than by the entrance of the star into a nebula, the possibility may be suggested that the disappearance of the chief nebular lines may coincide with the emergence of the star from the nebula.

Spectra of Stars in the Hercules Cluster M 13.

Mr. Pease has obtained an additional photograph of this cluster with the focal plane spectrograph, using a slit-width of 0.050 mm. and an exposure of 30 hours.

The slit was set 3″ south of the star Scheiner 373, which Barnard uses as his normal star, and stars are scattered over a distance of

4 minutes in an east-and-west line. Identification of 20 spectra is possible, though some are composite and represent several close stars. Spectra of some stars of Barnard's visual magnitude 15 are included.

Taking as units five divisions of the Harvard scale, we have 1 star of A_0, 6 of A_5, 9 of F_0, 3 of F_5, and 1 of G_0.

The mean of this determination is practically the same as that given by the 19 stars mentioned in last year's report. The two results combined, making a total of 39 stars, give the mean class of the cluster as F_0.

PROFESSOR KAPTEYN'S INVESTIGATIONS.

The papers by Professor Kapteyn mentioned in the last report as being nearly ready for the press, have been printed as Contributions Nos. 82 and 83 under the titles "On the Individual Parallaxes of the Brighter Galactic Helium Stars in the Southern Hemisphere, together with Considerations on the Parallax of Stars in General," and "On the Change of Spectrum and Color Index with Distance and Absolute Brightness. Present State of the Question." As a sequel to the first of these, a beginning has been made upon the investigation of the galactic helium stars between longitudes 150° and 216°, including mainly the constellation of Orion.

A great difficulty lies in the fact that the bulk of these stars is very near the vertex of motion. As a consequence, the derivation of systematic corrections to the proper motions Boss's Preliminary General Catalogue becomes very troublesome. On the other hand, such corrections are all-important, for, as a rule, the proper motions near the vertex are very small. Much labor was spent on this question, with the result that the accompanying corrections were applied to the proper motions in declination.

α	δ	$\delta\mu$
5^h to 8^h	−20° to −40°	+0".008
	0 " −20	+0.004
	0 " +20	0.000

The last of these is the most uncertain. It is, however, of little importance for the present purpose. The very large correction near declination −30° may well seem startling, but as several independent determinations all agree in yielding a large positive value, its reality seems well established. With the derivation of these corrections, the last link in the chain of arguments is furnished by which it is shown that the stars above and below galactic longitude 216° belong to two different groups. Particulars of further results are omitted, as they may still be considerably changed by a more detailed investigation.

The further elaboration of the subject was temporarily interrupted in favor of another, more urgent, investigation undertaken jointly by Professor Kapteyn and Mr. Adams. Mr. Adams finds that the radial velocities of F, G, K, and M stars having small proper motions are

smaller, on the average, than those given by Kapteyn and by Campbell for stars of all proper motions together. On the other hand, it had already been found that among the stars with large proper motions there occurs an excessive number of great radial velocities. It therefore becomes desirable to find the law which connects the average radial velocity with the corresponding average astronomical motion. The same investigation can easily be made to furnish, besides, a more conclusive test of the two star-stream theory than has yet been given by the radial velocities.

The investigation was extended not only to the stars observed at Mount Wilson, but also to the F, G, K, and M stars of Campbell's Catalogue. The following summary for the G stars will serve as an example of the first results of the investigation:

Mean radial velocities of G stars in kilometers per second.

Total centennial proper motion.	Authority.	λ			Mean.	5th col. / 3d col.
		60° to 90°	50° to 59°	0° to 49°		
0″.0 to 2″.6	Mt. Wilson and Lick.	6.9 (37)	9.6 (11)	12.8 (32)	9.6 (80)	1.86
2.7 4.9	Lick..............	9.6 (10)	13.6 (5)	12.8 (13)	11.8 (28)	1.33
5.0 9.9	......do...........	9.5 (18)	....	12.3 (7)	10.3 (25)	1.30
10.0 49.9	......do...........	14.95 (13)	19.3 (4)	23.6 (11)	25.8 (30)	1.58
≧ 50.0	Mt. Wilson and Lick.	22.9 (51)	38.0 (9)	45.6 (31)	32.1 (91)	1.99

The radial velocities have been freed from the sun's motion, and were all taken positively; λ is the distance to the nearest true vertex (18^h 12^m, $-12°$; or 6^h 12^m, $+12°$). The numbers in parentheses show the number of stars on which each result depends. For the elements of the sun's motion, apex $= 18^h$ 0^m, $+31°$; velocity $=20.0$ km. were adopted. The existence of the two star-streams is well shown by the increase in mean radial velocity with diminishing λ. The proportion of the numbers in the third and fifth columns is about what we should expect according to considerations based on the proper motions. The fact that this proportion also holds for the stars of very small proper motion is very important. It shows, even more strongly than earlier considerations, that the phenomenon of the two star-streams is not confined to the neighborhood of the sun, as has been suggested, but extends to the most distant regions for which we have the necessary data. The other spectral classes show perfectly similar results. There are one or two irregularities in the case of the K stars, the cause of which has still to be elucidated.

The gradual increase in the numbers of the last column is no less evident than the fact just considered. The phenomenon has not yet been exhaustively investigated; but this much may now be confidently stated: at least part of the increase, and perhaps the whole of it, is

to be attributed to the non-maxwellian distribution of the velocities, the large velocities being in excess. Whether, as a second cause, we shall have to admit that the velocities of the more luminous stars are less than those of the fainter stars, remains yet to be seen. Only the K stars have as yet been investigated in regard to this point. The result is, however, not decisive.

PHYSICAL LABORATORY.

INSTRUMENTS.

A concave-grating spectrograph of 15-foot radius, mounted vertically in the laboratory well and combining the useful features of the Rowland mounting with close temperature control, was completed in October 1913. With it the spectrum may be photographed from λ 2000 in the first order (scale 3.7 Å per mm.), to λ 7000 in the second order. The 5-inch grating, ruled by J. A. Anderson, is of high quality. For the study of the ultra-violet and the photography of extended regions of wave-length with moderate dispersion, the instrument supplements the facilities offered by the plane-grating spectrograph.

The fittings of the electric furnace have been improved so that the temperature may be held nearly constant during long exposures. Provision has been made for the operation of an arc within the furnace chamber, which permits a study of the arc *in vacuo* and a comparison with the effects given by the vacuum furnace. Various atmospheres about the arc and high pressures may also be employed.

The 50-k.w. transformer used for the furnace and "tube-arc" is being replaced by one of 100 k.w. giving voltages in 5-volt steps from 5 to 50 volts. This will permit the use of larger furnace tubes and give greater flexibility.

The larger articles of equipment purchased are a Gaede oil-pump for moderate vacua, a Leeds and Northrup testing-set and moving-coil galvanometer, a Wolff decade resistance, ratio resistance, standard resistance of 100 and 1,000 ohms, and a 4-inch plane grating ruled by Anderson, giving high intensity in the first-order spectrum.

Mr. St. John and Mr. Babcock have devised apparatus for simultaneously photographing spectra of the same source, or different parts of the same source, which has proved of great value in eliminating small instrumental shifts. By means of prisms the exposures are made rigorously simultaneous, differences in intensity being compensated by a rotating sector of variable opening.

For use in the measurement of strong magnetic fields Mr. Babcock has designed and constructed 8 test coils and 2 mutual inductances. The magnetic areas of the coils have all been calculated. He has also constructed a nickel resistance thermometer and adapted the Callendar recorder to show with it very small temperature variations in the ruling-

engine room. Changes of 0°.01 C. over a range of several degrees can be observed.

A number of special investigations of equipment have been made by Mr. Babcock, of which the following may be mentioned:

The absolute equivalent focal lengths of the 30-foot photographic and 13-foot visual lenses have been determined with our best Anderson grating, whose constant is known within 1 part in 3,000. Secondary standards of wave-length were employed exclusively, using different parts of the spectrum in both second and third orders. Four independent values of the equivalent focal length corresponding to zero scale reading for the 30-foot lens are 9,249, 9,250, 9,249, 9,250 mm. These are useful for the calculation of the scale of plates which contain no standards of wave-length.

A comparison of the Kenwood grating with our best Anderson 4-inch grating shows that the former is brighter in the third order, but less perfect in its diffraction pattern.

The set of three D. C. generators giving 1,650 volts has been connected up. Glass and quartz plates have been silvered with them by cathodic discharge in a vacuum chamber. Superior results have been obtained by this means, with less labor and uncertainty than is involved in the chemical processes.

The new interferometer plates of fused quartz recently acquired have been tested by means of the green mercury line. They were found equal to our best glass plates made by Jobin.

The relative retardations for two of our large compound $\lambda/4$ plates, one by Werlein for the red and one by Babcock for the blue, have been measured, a wide range in the spectrum being covered in each case. Curves have been prepared showing the relative retardation of the mica as a function of λ, from which the percentage of undesirable light transmitted has been calculated. It is found that the two plates suffice for the entire spectrum from λ 3500 to λ 7000 without introducing more than 2 per cent of undesirable light.

The Koch registering micro-photometer, now nearing completion, has been installed in position on its pier in the basement of the office building and the mechanical adjustment of its parts is complete. The sensitive string electrometer with its projection microscope is in adjustment. It has proved to be unaffected by either mechanical or electrical disturbances in the room since the wiring for the motor has been finally arranged. With a magnification of about 450 diameters, the trace of the filament upon the moving plate is entirely satisfactory for measurement. The only important unfinished part of the apparatus is the large plate-holder, which will be constructed after preliminary work has shown the most desirable dimensions. The two screws have runs of 21 cm. and 100 cm. respectively, and by means of interchangeable gearing can be so connected that the receiving plate moves 2, 10, 30, or 50 times as fast as the plate which is being measured.

We are greatly indebted to Professor H. S. Carhart for the painstaking construction of two batteries of Clark cells. The first, consisting of 140 cells, supplies the constant voltage for charging the plates of the electrometer. The second, of 110 cells, supplies the minute current which passes through the photoelectric cell to the filament of the electrometer. The cells consist of mercury, mercurous sulphate, zinc sulphate, and zinc, sealed up in small glass tubes, each one giving about 1.44 volts. They have been tested, and seem better adapted to our purpose than any other form of battery.

ELECTRIC-FURNACE SPECTRA.

The electric-furnace spectrograms made by Mr. King, 170 in number, have been mainly for a detailed study of the spectra of chromium and vanadium at different temperatures, and for an examination of the effect of hydrogen at varying pressures on the titanium furnace spectrum. Photographs have also been made of the furnace spectrum of nickel and of the ultra-violet region of iron, but are not yet reduced. Further work with the tube-arc has been deferred until a more powerful transformer is installed.

The range of wave-length covered in the investigation of chromium and vanadium is $\lambda\,3500-\lambda\,7500$, within which 867 chromium and 1,092 vanadium lines have been classified as to the temperature at which they appear and the rate of change in intensity as the temperature rises. The numerous lines in some portions of the spectrum and the difficulty in bringing out weak lines in other regions have required a variety of dispersions, combined with high resolving power, for which the new concave grating has been highly useful. A decided gain in the furnace spectra has resulted from the success attained by the Acheson Graphite Company in supplying special tubes of very high purity, so that no difficulty is experienced from blends with lines of foreign substances. Vanadium is found to resemble titanium in the richness of its furnace spectrum at the higher temperatures, the lines comparing in number closely with those of the arc, but showing large differences in relative intensity. Among the lines which persist at lower temperatures, many are faint in the arc spectrum. Chromium shows a wide diversity at different temperatures and many deviations from the arc spectrum. An important group of red lines, weak in the chromium arc, is found to be strong in the low-temperature furnace.

The effect of a hydrogen atmosphere on the enhanced lines of titanium was studied to determine whether their strength in the chromosphere and in some stellar atmospheres may be due to the presence of hydrogen. The experiments failed to show any strengthening of the enhanced lines, which appeared at low pressures with equal ease when hydrogen was present and when the furnace contained only a residue of air. But as the pressure of hydrogen was increased from 10 cm.

to one atmosphere, the enhanced lines steadily weakened, while the characteristic arc lines retained their full intensity. Variation of the amount of titanium vapor produced no material change in the strength of the enhanced lines. This evidence, in conjunction with the known phenomena of the arc and spark, points to a dependence of the enhanced lines upon the presence of high-speed electrons, which are known to be expelled from highly-heated matter and to be favored by reduced pressure.

DISSYMMETRIES PRODUCED BY THE SPARK DISCHARGE.

A preliminary set of observations, based on 77 photographs, has been made by Mr. King on the effect of a powerful condensed spark in rendering spectrum lines unsymmetrical to such a degree as to give virtual displacements when measured. Selected regions of the iron and titanium spectra from λ 3600 to λ 6500 were observed for the general character of the effect, its variation for lines of different classes, and its change with the wave-length. The use of high dispersion with the plane-grating spectrograph showed that the inner vapor of the spark produces a dissymmetry giving an apparent displacement toward the red, while that of the outer vapor gives lines coinciding with the arc. The low-temperature furnace lines and the enhanced lines show but slight susceptibility, while the varying degree to which other lines are affected appears to be closely related to their furnace classification. A few lines are unsymmetrical toward the violet. For iron and titanium the lines most strongly affected are in the region of shorter wave-length. This feature and the behavior of individual lines are against a direct relation with the pressure-effect, as is also the fact that the spark dissymmetry appears to agree in all details with that observed with the tube-arc *in vacuo* at low potential. Tests with polarizing apparatus gave no evidence of a connection with the effect of a strong electrical field observed by Stark. A quantitative study will be made with the registering micro-photometer. The subject has important astrophysical bearings, owing to the fact that the displacing agency in the spark may also be active in stars whose spectra show strong enhanced lines and thus indicate a condition in some respects similar to that of the spark.

VACUUM-ARC OBSERVATIONS.

A series of photographs of the vacuum-arc spectra of chromium and iron has been made by Mr. King. For some of the diffuse chromium lines the well-known narrowing effect of reduced pressure was found to be very pronounced and improved wave-length measures have been made. Many intensity differences for both chromium and iron appear between the vacuum arc and that in air. A reddish discharge at the positive pole of the iron arc was found to be due to a high intensity of the $H\alpha$ line. This part of the arc gave also strong bands of nitrogen, of which high-dispersion photographs were obtained.

INVESTIGATION OF THE IRON ARC.

In the investigation of the relation between the iron spectrum and the corresponding solar lines, and in the determination of standards of wave-length, it was found that a detailed study of the iron spectrum was required as a preliminary. One phase has been the examination by Mr. St. John and Mr. Babcock of the changes in wave-length in the arc at atmospheric pressure that depend upon the portion of the arc used and upon the current strength. This involved a comparison of the spectrum near the pole and at the center of the arc. In the effort to carry the comparison to the third decimal, great difficulty was encountered in obtaining plates free from instrumental shifts of very small but determinable amounts. These were finally eliminated by making the exposures rigorously simultaneous. The exposures thus began and ended at the same moment, one being continuous and the other rapidly intermittent. A similar arrangement was used in comparing arcs with different current densities.

Comparisons have been made between the center and negative pole which involve about 1,600 lines between λ 2900 and λ 6700. About 250 lines were found for which the wave-lengths at the negative pole are greater by amounts exceeding 0.015 Å than those at the center, while for about 50 lines the wave-lengths at the negative pole are less by amounts exceeding 0.015 Å. The differences in wave-length between the positive pole and the center are of the same sign but less in magnitude.

In an arc 6 mm. long, carrying a current of 6 amperes—that recommended by the Wave-length Committee of the International Union for Cooperation in Solar Research—the differences are of the order of 0.01 Å between the center and a point 1 mm. from the negative pole. In a 12-ampere arc the wave-lengths of the two classes of lines are respectively longer by 0.007 Å, and shorter by 0.012 Å, than in a 4-ampere arc. Between arcs carrying 5 and 7 amperes, the displacements of the lines showing positive shifts do not exceed 0.001 Å, but those with negative displacements still give easily measurable shifts.

The reality of such displacements being open to question because of the unsymmetrical widening of the lines, the point has received particular attention. The exposure time at the pole was decreased until the lines were weaker and narrower at the pole than at the center of the arc. The displacements were still large. Measurements with the Hartmann micro-photometer gave displacements of the maxima of the lines of the same order of magnitude as those found with the measuring microscope.

The displacements are indirectly related to pressure shift. The lines showing a longer wave-length at the negative pole are those belonging to groups giving very large positive pressure shifts; those showing a shorter wave-length at the negative pole are lines giving

large negative pressure shifts. But the effect appears not to be due to differences of pressure in the arc, as other lines with pressure shifts of 0.009 Å per atmosphere show no determinable displacements, while a difference in pressure of the order of an atmosphere is required to account for the large displacements observed. Further, the displacements observed do not vary as the cube of the wave-length, as in the case with pressure shift. Provisionally they are considered to be due to changes in density, but the question is still under investigation.

The remaining 1,300 lines compared show no measurable difference in wave-length depending upon the portion of the arc used or current strength. Their independence of ordinary arc conditions makes them eminently suitable for standards of wave-length.

STANDARDS OF WAVE-LENGTH.

The critical study of the iron arc by Mr. St. John and Mr. Babcock has shown what lines can be employed with confidence as standards, what lines must be used with caution, and under what arc conditions they yield consistent results. Unfortunately many of the tertiary standards and some of the international secondaries belong to these groups of questionable lines. Between λ 2900 and λ 6700 there are 1,300 lines of good quality, and approximately 300 lines of the questionable groups. No class of lines is distributed with even approximate uniformity through the spectrum, so that a wide region, from λ 5500 to λ 6000, is without a line of high quality, and from λ 4500 to λ 5000 the great majority of the lines belong to the questionable classes. In these two regions both the secondaries and tertiaries must of necessity include questionable lines. It has thus been necessary to establish the limiting arc conditions which will yield wave-lengths of the desired precision. The source recommended by the Committee of the International Union for Cooperation in Solar Research is an arc 6 mm. long between iron terminals 7 mm. in diameter, carrying a current of 6 amperes. The investigation has shown that the current may vary between 5 and 7 amperes without producing a variation in wave-length exceeding 0.001 or 0.002 Å, and that the light should not be taken from a point nearer to the negative pole than 2 mm. nor nearer the positive pole than 1 mm. In view of these results it has seemed advisable to Mr. St. John and Miss Ware to redetermine the wave-lengths of the suspected lines under strictly standard conditions, and to omit lines of this character in extending the measurements into the ultra-violet, where lines of high quality are the prevailing type. The measurement of the sun-arc plates for the wave-lengths on Mount Wilson and the pole-center plates for the wave-lengths in Pasadena are in progress. With the installation of an interferometer on the mountain, a series of secondary standards will be determined for use at that elevation.

The investigation by Mr. St. John and Mr. Babcock of the behavior of lines under laboratory conditions is still in progress—in particular a

determination of the conditions under which displacements occur that are not due to pressure differences in the arc. There are indications that the reversals of lines give somewhat different results, a subject not yet fully worked out. The importance of determining any changes of wave-length due to the presence of the vapors of other elements is very great, because of the conditions of mixture existing in sun and stars. It has been reported by Barus that when some elements are present only in traces, the wave-lengths are shorter than when the given element is the main constituent. An investigation of alloys in which an element is present in varying proportions is being carried on. The method of simultaneous exposures makes it possible to use a constant light source as a standard in reference to which the effects of dilution may be determined with high precision. Other elements than iron show the pole-center effects, which probably are of influence in the determination of the wave-lengths of the elements in international units now in progress in various laboratories. A direct comparison of pole and center offers the speediest way of detecting the questionable lines, and such an examination will be made of elements in which the work of the Observatory is particularly concerned.

INVESTIGATION OF THE ZEEMAN EFFECT.

The work upon the Zeeman effect accomplished by Mr. Babcock includes the collection of measures for large numbers of lines for many elements, and the determination of the absolute separations for certain selected lines and the evaluation of e/m.

Data from the measures on a total of 28 plates are available for 903 chromium lines between λ 2394 and λ 6479, measured on two or more plates; 769 iron lines between λ 3440 and λ 6678, mostly measured on more than one plate; 643 vanadium lines between λ 2978 and λ 6625; and a few lines belonging to titanium, manganese, zinc, cadmium, and barium. The field-strength used has generally been near 30,000 gausses, but some plates have been taken with 4,000 gausses. The results have been summarized, and their reduction to a common field-strength and comparative studies are in progress.

For the standardization of our values of the Zeeman separation, the following method of measurement of field-strength has been adopted: A minute coil of very fine wire, wound upon a spool of ivory or hard rubber, is connected in series with the secondary of a standard mutual inductance, a 10,000-ohm resistance, and a sensitive ballistic galvanometer of long period. The coil is inserted into the field, the galvanometer brought to rest, and the coil suddenly removed to a considerable distance from the field. After reading the deflection, the coil is inverted, and the process repeated, giving a deflection of opposite sign. The double deflection obtained by combining the two readings is then evaluated by reversing known currents in the primary of the mutual inductance.

Three series of measures have been made, giving values of *e/m*, as follows: 1.754, weight 1; 1.762, weight 14; 1.761, weight 3. The weighted mean is 1.761, with an uncertainty of not more than 2 units of the last place.

These values are based upon 65 lines measured on 46 plates. Nine different field-strengths were used and 16 independent measures of H were made. The lowest field was 26,560 and the highest 31,880 gausses. The results were obtained by means of plane-grating spectrographs, the current measurements being in terms of resistance and the e. m. f. of a standard cell. A fourth series, using an interferometer for the spectrum measures and a control of the current strength by deposition of silver, is being undertaken.

COMPUTING DIVISION.

The Computing Division has remained throughout the year under the direction of Mr. Seares.

Miss Bach was appointed to the division on January 1, and has been engaged in the measurement of laboratory plates. Seventeen plates for the Zeeman effect and 22 for the evaluation of *e/m* have been measured and reduced. She has also done some work upon spectrum lines with the micro-photometer.

Miss Burwell has given her attention to the investigations in stellar spectroscopy. She has measured and reduced 600 stellar spectrograms and has computed a large number of star constants and reductions to the sun. In addition to the stellar work, she has collected and reduced the measures of the flash spectrum without an eclipse, and has measured several test-plates for the 100-inch mirror.

Miss Ensign has also been engaged with the stellar spectroscopic work. She has measured and reduced 600 spectrograms, has calculated and checked star constants and reductions to the sun, and has measured several pairs of test-plates for a 30-inch and for the 100-inch mirror.

Miss Felker was appointed to the division October 14, 1913, but was obliged to resign in April on account of ill health. Her time was divided between the measurement and reduction of spot spectra and general magnetic field plates, and computations relating to the photometric work upon polar stars and Selected Areas.

Miss High has been occupied mainly with the work in stellar photometry. She has measured and reduced 140 photometric plates. In addition, she has measured several spot spectra and has given a large amount of time to the reduction of these and similar plates and to computations relating to the sun's general magnetic field.

As in the past, Miss Lasby has been engaged mostly with the investigations in stellar spectroscopy. She has measured about 700 spectrograms for radial velocity and has computed the reduction constants of over 200 stars. The absolute velocities for 40 stars of known paral-

lax have also been computed. In addition, the measurement of the laboratory plates of the iron spectrum undertaken for Mr. Gale for the determination of the shift at low pressure has been completed. A few photographs of iron spectra for Zeeman effect and several solar rotation plates of the new series were also measured.

Miss McClees joined the division May 15, and at present is occupied with measures and reductions of spot spectra and miscellaneous computations.

Up to the date of her resignation in January, Mrs. Nichols continued her work with the laboratory plates, about 100 being measured and reduced. Much time was also given to the classification and collection for publication of the results on vanadium and chromium, and to the reductions for the determination of the constant e/m.

Miss Shumway has continued to serve as recorder and computer in connection with the stellar spectroscopic work. Besides reducing several hundred spectrograms for radial velocity, she has done the computing necessary for the extension of the reduction tables used in this work.

Miss Richmond has measured and reduced 156 stellar photometric plates and 24 solar photographs relating to spot spectra and the sun's general magnetic field. A month was occupied with computations on the general magnetic field, and much time has been given to miscellaneous computations, proof-reading, etc.

Miss Smith has continued with the routine reductions relating to the spectroheliograph plates. The areas of the calcium flocculi have been determined on 201 spectroheliograms, and 237 prominence plates have been measured. All reductions, including the fluctuation curves of the calcium flocculi and prominences, are completed to May 8, 1914. Three hundred prints of spectroheliograms have been made, and the data for a statistical investigation of sun-spot grouping are being collected and classified. Miss Smith also superintended the transfer of the 12,000 solar photographs from the old vault to that of the new office building, and has checked their present arrangement by the serial numbers.

Miss van Deusen was engaged until January with star counts upon 35 of the photographs of globular clusters made by Mr. Pease. Since then she has measured and reduced about 20 plates taken for the determination of the pole and center shifts of the iron arc and for the comparison of the shifts in the solar and iron-arc spectra. She has also made the screw tests for two new comparators.

Miss Ware has continued with the work connected with the solar investigations of Mr. St. John. An extended series of measures has been made upon laboratory plates for the determination of the characteristics of the spectrum of different parts of the arc and for the comparison of arc and solar spectra. For the latter purpose a number of solar plates have also been measured. In addition, there has been much computation and compilation, all relating to the solar investigations.

Miss Wolfe served as librarian until November 1. Since then she has devoted her time exclusively to the reduction and discussion of results relating to the work of stellar photometry, the sun's general magnetic field, and the fields associated with sun-spots.

On November 1 Miss Haines resumed her position as librarian and in addition has given assistance in the compilation and tabulation of results relating to the work of the division. She has also aided in the editorial work and in the preparation of manuscripts, proof-reading, etc.

The library has been increased by 545 bound volumes during the year—271 by purchase, 205 by binding, and 69 by gift. The total number of volumes is now 3,676.

The Observatory is much indebted to Mrs. Katharine Hooker for a large portrait, in oils, of the late Mr. John D. Hooker, and to Mrs. Henry Draper for a portrait of the late Dr. John S. Billings and several original negatives by Dr. Henry Draper.

CONSTRUCTION DIVISION.

WORK OF THE INSTRUMENT SHOP.

The ruling-machine has advanced to the point where visible progress is slow, on account of the extreme delicacy of the various operations involved. Mr. Jacomini spent several weeks with Dr. Anderson at the Johns Hopkins University in the autumn, familiarizing himself with the various adjustments and tests of the Rowland-Anderson ruling-machine, and experimenting with certain alloys which promise to afford good material for grating plates. He also spent a week at the Fore River Ship Company's yards at Quincy, Massachusetts, inspecting the work in progress on the 100-inch reflector mounting. On his return to Pasadena he devoted himself to the long and tedious task of grinding and straightening the ways. The machine was inclosed in a house of wood and glass, which materially improves the temperature control. Tests with a Callendar recorder showed a maximum temperature range of about 0°.01 C. in the course of a month, with much smaller daily fluctuations. The hydraulic driving system was perfected, with most satisfactory results, through the improvement of a commercial water-motor of 0.1 horse-power, which now gives ample power with a head of only about 33 feet. The experiments on various forms of end-thrust bearings led to the adoption of a ruby-steel combination, which leaves nothing to be desired. A reconstructed ruby about half an inch in diameter was given a plane figure by Mr. Jacomini, and mounted in conjunction with a highly polished convex surface of hardened steel. Optical tests show that a high degree of precision has been attained in figuring and centering these bearings. The machine is now nearly ready for the exhaustive cross-ruling tests devised by Dr. Anderson.

In addition to the work on the mounting of the 100-inch telescope, which occupied about half the time of the instrument shop, the large

Koch registering micro-photometer, with bed 12 feet long, has been completed, and much other work accomplished. This includes many improvements in the cœlostat and second mirror support of the 60-foot tower telescope, the construction of running gear, driving mechanism, and other parts for three domes, a large figuring attachment for the 100-inch grinding machine, completion and erection of the 15-foot concave-grating spectrograph, and much work on the 10-inch portrait-lens mounting, 4 by 5 inch comparator, two 8-inch measuring machines, vacuum-spark apparatus for the large electromagnet, machine for grinding rails of dome for 100-inch telescope, addition to 8 by 10 plate-carrier, addition to Cassegrain spectrograph, experimental work on liquid prism, repairs and alterations of instruments, repairs on power plant and auto truck, repairing and scraping of ways and bearings of 56-inch lathe, etc.

A Cincinnati No. 1½ motor-driven cutter and tool-grinder, a large motor-driven power-saw equipped to cut 24-inch sheets and 18-inch rounds, and a 2 horse-power motor Aerial grinder were added to the instrument-shop equipment.

THE ONE-HUNDRED-INCH TELESCOPE.

Optical work on the 100-inch mirror has been continued by Mr. Ritchey during the year, and an almost perfectly spherical figure has now been attained. The edge support referred to in the last annual report has been found to work excellently, and no distortion of the mirror due to this source has been observed in recent tests. A very slight amount of astigmatism apparently still remains to be corrected, but the zonal errors have been almost completely eliminated. It is thought that if a spherical figure entirely free from zones can once be secured it will be possible in the course of parabolization to keep the mirror essentially free from such errors.

As the work on the spherical figure of the mirror has progressed it has been found necessary to adopt certain additional precautions to protect it from temperature variations. Thus, in spite of attempts to produce a thorough mixture of the air in the optical room and in the testing hall by means of fans, there is sufficient stratification to affect the tests seriously, as well as sufficient temperature variation between the top and the bottom of the mirror, when in a vertical position, to introduce a small amount of distortion. To improve the first of these conditions a number of large tubes made of paper over a wooden framework have been distributed throughout the optical room, through which a circulation of air is obtained by means of fans. Considerable improvement is noticed in the tests when this arrangement is used. To protect the edge of the mirror a thick band of woolen wadding inclosed in canvas was placed between the edge band and the glass. A similar cushion beneath the glass affords excellent protection to the

back of the mirror. This material has proved so satisfactory that an edge band of the same construction has been made for use with the 60-inch mirror on Mount Wilson.

In preparation for the work of parabolizing the mirror a number of modifications have been made in the grinding machine. The most important of these is that of the large arm carrying the grinding and polishing tools, which has been changed so as to admit of giving straight strokes of variable length. Several wooden polishing tools have been completed in readiness for the parabolization. The 60-inch plane mirror to be used in testing the figure of the larger disk is also entirely finished.

One other important auxiliary piece of apparatus recently completed is a metal frame carrying knife-edge, light-source, and the plate-holder intended for use in the Hartmann photographic tests. The plate-holder is provided with screw adjustments, so that in case of necessity the observer may guide during the exposures and so avoid distortion of the photographic images due to the settling of the 100-inch mirror upon its edge band.

Work on the 100-inch mounting has progressed in our instrument shop and at the Fore River shops, where the larger parts are being built under the supervision of Professor Peter Schwamb, acting as our representative. The north and south pedestals and bearings, mercury floats, polar axis, and declination bearings have been nearly completed, and work is in progress on the tube. It is expected that all of this heavy work will be finished and assembled at Fore River in time to permit shipment to Pasadena, by way of the Panama Canal, early in 1915.

Meanwhile the smaller parts and accessories are being made in our own instrument shop. These involve much work of high accuracy. The driving clock, which is nearly completed, required more than half a ton of bronze castings and nearly $1\frac{1}{2}$ tons of iron castings, in addition to the 2-ton driving weight. The teeth of all the gears in the clock train have been accurately spaced with the aid of circles graduated by Mr. Jacomini. Other parts of this telescope in progress during the year include spectrograph, coudé mechanism, mirror-support system and casing, bearings, motor-control apparatus, etc.

The work of erecting the steel building on Mount Wilson is described below. The dome, which has been set up by the Morava Construction Company at their works in Chicago, will soon be ready for shipment. We hope, under favorable weather conditions, to complete its erection on Mount Wilson next summer, so that the mounting may be set on its pier in the autumn.

MOUNTAIN TRANSPORTATION.

The necessity for transporting to Mount Wilson material of large dimensions and great weight for use in the construction of the 100-inch telescope has made it desirable to undertake extensive improvements

of the mountain road. For about one-half of the distance the road-bed has been widened from 3 to 8 feet, with a corresponding gain in safety and ease in making the numerous turns with the loaded trucks. The work was begun on January 1 and continued until April 26, when it was interrupted in order that transportation to the mountain might not be obstructed. Owing to unusually heavy rains occurring after the work was under way, the labor was considerably increased.

Notwithstanding the loss of the 3-ton truck by accident, this means of transportation has proved efficient and expeditious. The 1-ton truck has made daily trips with supplies and members of the staff, excepting during the interval of work upon the road and an occasional day of bad weather. A new 3-ton Mack truck, of the same make and type as the old one but better adapted to our purposes, has been purchased and was in daily operation during the construction season on the mountain. With it about 275 tons of material, mainly for the 100-inch telescope, the reconstructed 60-foot tower telescope, and the 10- and 6-inch telescopes, have been hauled to the summit.

CONSTRUCTION ON MOUNT WILSON.

The work on the 100-inch telescope ended last year with the completion of the pier and the footings for the dome. During the present season the steel framework and the inner sheet-metal covering of the circular building, 100 feet in diameter, which incloses the instrument, has been put in position. The structure is complete up to the rails which are to carry the dome, and these have been accurately adjusted and are being ground. The concrete floor has also been laid. The circular form for the rails has been assured by mounting on a pivot support at the center of the building a skeleton steel arm, 50 feet in length, which can be rotated throughout the entire circumference. For the finishing of the rails a motor-driven grinder was attached to the end of the arm, which will later serve as a boom for the erection of the dome. The power required for the riveting of the building and dome is supplied by an 8 by 8 inch air-compressor, temporarily installed in the base of the pier.

The next most important piece of work is the reconstruction of the 60-foot tower telescope, which is now nearing completion. The outer tower for the support of the 20-foot dome that will shelter the cœlostat is finished, the tube is in position, and the reinforced-concrete observing building is practically finished. The dome is not yet in place, but will be provided before the winter season begins. In the meantime, the cœlostat and driving clock are being thoroughly overhauled and improved in the Pasadena shops.

Good progress has also been made upon the buildings for the 10-inch photographic and the 6-inch visual telescopes. Reinforced-concrete buildings have been constructed for both instruments, and the 20-foot domes are now being erected.

Aside from the larger pieces of construction, much miscellaneous work has been done. The steel roof of the power-house extension has been built and erected. An additional room to the janitor's cottage has been built and the few remaining electric wires above ground have been placed in underground conduits. A 6-inch centrifugal exhaust fan with a galvanized pipe leading to the bottom of the pit of the 150-foot tower telescope has been installed for the reduction of the humidity in the pit; an automatic switch board with remote control for five motors and direct control for two has been constructed by the power-house shop for the 60-foot tower telescope; a still similar to that used with the 25 horse-power engine has been built for the exhaust pipe of the 50 horse-power engine, which yields all the distilled water required on the mountain and in the laboratories in Pasadena. As protection against fire, much dead brush has been removed and metal-covered shutters have been attached to the windows of the laboratory, power-house, and battery room. Some of the smaller buildings have been repainted, and many minor changes and improvements have been made in the buildings and instruments.

The Observatory has also made a few additions to the 40-foot tower of the Smithsonian Astrophysical Station.

NUTRITION LABORATORY.*

FRANCIS G. BENEDICT, DIRECTOR.

The Nutrition Laboratory is now firmly establishing itself as a research center for work with several scientific institutions in Boston. At present a respiration apparatus with accessories belonging to the Nutrition Laboratory is installed in a special room provided for it by the management of the New England Deaconess Hospital, this apparatus being used chiefly for studying the metabolism of diabetics. The trustees of the Massachusetts General Hospital have also set aside a special room in which the Nutrition Laboratory has installed a respiration apparatus with accessories for studying the gaseous metabolism of normal infants; experiments have been made with this apparatus almost daily for the past two years. More recently the trustees of the Boston Lying-In Hospital have been interested in the researches, and material for studying the metabolism of normal new-born infants has thus been readily and rapidly acquired.

Recently a special cable has been laid connecting delicate electrical apparatus in the Nutrition Laboratory—such as the string galvanometer and oscillograph—with certain research rooms in the new Thomas Morgan Rotch Jr. building of the Infants' Hospital, which provides facilities for studying by photographic registration the pulse-rate of infants. By these intimate affiliations with other institutions a large number of active workers interested in the problems of metabolism are brought into closer touch with the Nutrition Laboratory.

LABORATORY CHANGES.

The approaches to the building have been improved by the laying of tarvia pavements and granolithic sidewalks. The grounds in the rear of the building have also been re-graded in accordance with the plans of a landscape architect in harmony with the grounds of the adjacent buildings.

To provide for photographic registration, which was but tardily used by this Laboratory in its research work, one of the basement rooms has been reconstructed and a Thoma oscillograph permanently installed for the study of the electrical action of the heart and other delicate physiological activities which are best recorded photographically. This room with its equipment has been placed in charge of Professor H. Monmouth Smith, of the Laboratory staff.

A special laboratory for the use of the Director has been constructed and is being equipped with apparatus, so that hereafter the develop-

*Situated at Boston, Massachusetts. (For previous reports on work in nutrition, see Year Books 2–12.)

ment of apparatus and technique may not be disturbed by the requisition of the apparatus for other experimental work.

The wood and zinc floors in the rooms for research with animals have been replaced with new floors of cement and terrazza. This is a substantial and much-needed improvement.

Owing to the concrete construction of the building, much difficulty has been experienced in the past (particularly in the winter, when the snow has accumulated on the roof) by the condensation of moisture on the ceilings of rooms on the third floor of the laboratory. This water, dropping upon the apparatus in these rooms, has caused frequent annoyance. The ceilings have therefore been painted with a specially prepared cork paint, such as is used on battleships and submarines to prevent undue condensation of moisture.

A new inter-communicating telephone system, more especially adapted to the needs of the Laboratory, has been successfully installed.

ADDITIONS TO EQUIPMENT.

Reconstruction of the bed calorimeter.—Heretofore the active experimenting on technique, which required the continual use of the bed calorimeter and changes in its construction, has made it impossible to give this apparatus a permanent form. Inasmuch as there was no immediate prospect of a fundamental change in the principle or technique of the apparatus, it was completely reconstructed during the summer of 1914 in accordance with the latest and most approved design, the mass of metal between the copper and zinc walls being removed, and the whole apparatus made substantial and permanent. In this construction we profited much by the experience of Professor Lusk and his co-workers at Bellevue Hospital. The apparatus will be given the usual electrical and alcohol check-tests and thereafter used continuously for experiments with normal and pathological subjects.

Respiration apparatus for muscular work.—In connection with an extensive study of the metabolism incidental to walking, a special modification of the unit form of respiration apparatus in use in this Laboratory was adjusted to the treadmill designed by Mr. Metcalf, formerly of our staff. The respiration apparatus is a somewhat modified form of the apparatus employed by Dr. Cathcart in his experiments on the muscular work of bicycle riding. The apparatus functionates perfectly and an extensive research was carried out with it in 1914 by Dr. Murschhauser. Supplementary apparatus for recording the height to which the body was moved, the number of steps taken, the distance walked, and similar measurements, was likewise designed and constructed for this research.

Dog treadmill.—A dog treadmill, of the admirable form devised by Professor Franz Tangl of Budapest, was secured from Professor Tangl's

former mechanician, Junkunc, now in Chicago. With this apparatus the distance traveled by a dog may be accurately measured; it may also be used for securing certain amounts of exercise or muscular work in experiments with animals in which known amounts of work are to be performed.

Respiration apparatus for small animals.—The unit form of respiration apparatus has also been adapted to the study of small animals by using a chamber with a swinging cage for recording the movement of the animal. The accuracy of the apparatus has been demonstrated by the usual tests. With this respiration apparatus experiments may be carried on without interruption for several days and the animal maintained in an artificial atmosphere as long as desired. During the past year the apparatus has been used for an extensive series of experiments on the gaseous metabolism of rabbits living in an atmosphere of nearly pure oxygen. By using a spirometer, accurate measurements of the oxygen consumption were obtained.

Apparatus for photographic registration.—The Laboratory has acquired an unusual collection of apparatus for photographic registration, including the Blix-Sandstrom kymograph with photographic registration appliances, the kymograph of Frank, the Edelmann-Morse apparatus, the apparatus employed by Thoma with the oscillograph, and that used with the string galvanometer manufactured by the Cambridge Scientific Instrument Company. Special forms of apparatus for photographic registration were employed by Professor Dodge in connection with his psychological observations.

Miscellaneous equipment.—The rapid accumulation of reprints which are continually being presented to the Laboratory, and the necessity for a moderate enlargement of the library facilities, together with the increasing number of workers needed for computation, abstracting, and translation, made a complete rearrangement of the library and computing room necessary. In this rearrangement an extensive addition has been made to the library shelving, and modern fireproof steel cabinets and filing cases have been provided for the storage of the important scientific records, including all original data, kymograph records, and calculated material.

COOPERATING AND VISITING INVESTIGATORS.

Although the number of available subjects is small for studying the particular problems in diabetes which at present interest us, Dr. E. P. Joslin has continued his cooperation in the study of metabolism in severe diabetes.

Dr. Fritz B. Talbot has also continued his active cooperation in the research on the metabolism of infants, especially in arranging for and carrying out the observations on the metabolism of the new-born in

connection with the Massachusetts General Hospital and the Boston Lying-In Hospital.

M. Lucien Bull, Sub-director of the Institut Marey, in Paris, was commissioned by the Société Scientifique d'Hygiène Alimentaire et d'Alimentation Rationelle de l'Homme, of Paris, to spend several weeks at the Nutrition Laboratory in the fall of 1913, in studying the design of the respiration calorimeter. During his visit here, M. Bull gave invaluable assistance by his suggestions as to the installation of the photographic registration apparatus, optical instruments, and similar apparatus, a subject in which he has specialized for many years.

Dr. Carl Tigerstedt, of Helsingfors, spent a few months at the Laboratory, familiarizing himself with respiration apparatus of various forms here employed.

Dr. Hans Murschhauser, of the Kinderklinik in Düsseldorf, was connected with the Laboratory for six months as Research Associate of the Carnegie Institution of Washington. During this time he studied the various respiration apparatus and carried out an extensive research on the metabolism incidental to the work of walking, using a professional athlete as a subject.

Professor Howard T. Karsner, of the Harvard Medical School, has actively cooperated in studying the physiology and pathology of the respiration of rabbits in an atmosphere containing a high percentage of oxygen.

Dr. F. E. Wells, of the McLean Hospital, cooperated in an investigation upon the psychological effects of moderate doses of alcohol, his unusual experience in the free association tests being of special benefit.

Dr. J. L. Gamble studied for several months the technique of the infant respiration apparatus, acquiring proficiency in its use.

Dr. J. H. Means, of the Massachusetts General Hospital, has cooperated with Mr. H. L. Higgins, of the Laboratory staff, in a series of observations on the effects of drugs upon the alveolar air and the gaseous metabolism.

Dr. H. W. Stevens, also of the Massachusetts General Hospital, cooperated in a study of the insensible perspiration and muscular activity of infants.

STAFF NOTES.

Professor Raymond Dodge was unable to secure longer leave of absence from Wesleyan University and hence was obliged to terminate his very interesting series of observations on the psychological effects of moderate doses of alcohol. The year spent at the Nutrition Laboratory by Professor Dodge was characterized by great experimental activity and a keen interest in all of the affairs of the Laboratory. There was scarcely a department of the work which was not materially assisted by his counsel and his unusual technical skill.

Professor Walter R. Miles, of Wesleyan University, has been appointed physiological psychologist and placed in charge of the laboratory formerly used by Professor Dodge.

Professor H. Monmouth Smith visited several cities in Europe in behalf of the Laboratory for the purpose of purchasing and arranging for the construction of apparatus, and for conference with various scientists. After a few weeks in Hamburg, Bonn, Heidelberg, and Berlin, it was necessary for him to terminate his trip on account of the European war.

Mr. H. L. Higgins was granted leave of absence for several months in the summer to cooperate with the New York State Commission on Ventilation.

INVESTIGATIONS IN PROGRESS.

Metabolism in diabetes mellitus.—In studying certain important problems in diabetes mellitus, it has been extremely difficult to secure cases of the type especially suitable for this kind of observation. Consequently the accumulation of data has not been so rapid as in the earlier series of experiments. The establishment of a special laboratory in the New England Deaconess Hospital, equipped with a respiration apparatus for such studies, and the personal active cooperation of Dr. Joslin, will, it is hoped, enable greater progress to be made.

Metabolism of infants and the new-born.—No single research has progressed with greater regularity and with less interruption than the study of the gaseous metabolism of infants at the Massachusetts General Hospital, which has been undertaken in cooperation with Dr. Fritz B. Talbot. A considerable number of the results have recently been reported in Publication No. 201 of the Carnegie Institution of Washington. The successful prosecution of this work has warranted its continuance and, indeed, the program has been elaborated during the past year by including a special study of the gaseous metabolism of the new-born, almost daily observations being made with infants but a few hours old. These observations have been made possible by the cooperation of the Boston Lying-In Hospital, and the collection of data is rapidly proceeding.

Metabolism incidental to walking.—Dr. Hans Murschhauser, during his sojourn in the Nutrition Laboratory, as Research Associate of the Carnegie Institution of Washington for the year 1913–1914, carried out an extended research upon the metabolism incidental to walking, employing the treadmill devised in this Laboratory and a special form of unit respiration apparatus. Dr. Murschhauser made his observations upon the athlete used by Dr. Cathcart in his earlier research on the metabolism during bicycle riding. The walking experiments covered a period of several months and a large mass of data was accumulated. The computations of these data are now being verified and the report is being prepared for publication.

Normal metabolism of men and women.—Although sufficient material has been accumulated in the work of the Laboratory to warrant the publication of a series of observations on 89 normal men and 68 normal women, the data were secured for the most part upon individuals approximating 20 to 25 years of age. The attempt is now being made, therefore, to extend these observations to include studies of the metabolism of both younger and older individuals. This work is being carried on with the assistance of Mr. L. E. Emmes, of the Laboratory staff.

Metabolism of the obese.—The supposedly anomalous metabolism changes in the obese, which have long puzzled physicians, have been the object of study during the past winter. With the cooperation of Dr. E. L. Locke, of Boston, studies have been made of several extremely obese people who are otherwise normal. The investigation is still in progress and important data are being accumulated. These experiments are being made by Mr. Emmes with the unit respiration apparatus in this Laboratory and will ultimately be supplemented by direct calorimetric measurements.

The conversion of carbohydrate to fat in the animal body.—Conferences with numerous scientists on my several European tours have shown that one of the most important direct calorimetric observations needed is that of the energy transformation incidental to the conversion of carbohydrate to fat. It has already been shown in this Laboratory[1] that, even with dogs which are deprived of the pancreas, it is possible to secure the formation of fat from carbohydrate; but certain animals lend themselves particularly to this study, namely, swine and geese. As the classical observations on this subject of Bleibtrau in Pflüger's laboratory were unfortunately not accompanied by calorimetric observations, a study has been made during the past winter of the conversion of carbohydrates to fat with geese as subjects, the carbon-dioxide production, oxygen consumption, and the heat-production being measured simultaneously. Six full-grown geese were used in each experiment, these being put in a special form of cage and, after surfeit feeding, placed inside of the bed calorimeter. The preliminary data for this extended series of observations were taken by Professor Smith to Europe for conference with several scientists especially interested in this problem.

Comparison of the methods of determining the respiratory exchange.—The experimental work in this investigation, which has been in the hands of Mr. T. M. Carpenter, has been supplemented by a series of control tests of the Tissot methods, by burning small amounts of ethyl alcohol in a specially constructed apparatus.

Considerable time during the past year has been spent in assembling the large amount of data collected in this research, which has extended

[1] Morgulis and Pratt, Am. Journ. Physiol., 32, p. 200. 1913.

over several years. A careful analysis has been made of the results obtained and the different sources and amounts of errors involved in the several methods studied have been thoroughly considered. The computations have been made and checked and the manuscript is ready for publication.

Influence of moderate doses of alcohol upon psychological processes.—In connection with the extensive program for the investigation on the effects of the ingestion of moderate doses of alcohol, Professor Raymond Dodge, with several assistants, has actively prosecuted the study of the psychological effects of such doses. While it would not be possible in the space of one year to carry out any large part of the elaborate program outlined for this important subject, nevertheless the work has progressed with unusual rapidity and accuracy and it is believed that the report now being prepared will be of an authoritative nature.

The after-effects of the ingestion of alcohol upon the nervous system.—An extended series of observations made by Professor Miles, on a subject who had previously served in the work of Profesors Dodge, shows extremely interesting after-effects. The problem is still under investigation.

The effect of alcohol upon the alveolar air and respiratory exchange.—By determining the alveolar carbon-dioxide tension and simultaneously the total respiratory exchange, Mr. H. L. Higgins has studied the influence of small doses of alcohol (10 to 25 grams) to secure information upon the rapidity of combustion of alcohol and its participation in the total respiratory exchange.

The effect of small doses of alcohol on skilled muscular processes.—Typewriting was chosen as a convenient and extensively used form of muscular activity on which the influence of alcohol could be studied with advantage. The subjects operate the typewriter during approximately 20 minutes in each half-hour experimental period, the remaining time being occupied in measurements of related neuro-muscular processes. A complete kymographic record supplements the typewritten sheet, making possible the analysis of results. The investigation is being carried out by Professor W. R. Miles.

Effect of therapeutic agents upon the respiratory exchange.—A series of experiments to study the effect of several drugs used in therapeutics upon the respiration and gaseous exchange has been made by Mr. Higgins in conjunction with Dr. J. H. Means, of Professor Edsall's clinic at the Massachusetts General Hospital. The drugs used in these experiments were antipyrene, atropine, caffeine, camphor, codeine, heroine, morphine, and strychnine. The alveolar carbon-dioxide tension of the subject was found before and at different intervals after the administration of the drug, the object being to find if the sensitivity of the respiratory center to carbon dioxide was affected. Simultaneous determinations of the respiratory exchange afforded opportunity to

study any broncho-constrictor or broncho-dilator effects of the drug from the volume of the dead space of breathing in the individual experiments and also supplied data as to variations in the gaseous metabolism due to the drug.

The influence of alcohol on sense thresholds.—With the development of further accurate techniques for studying the sense thresholds, this phase of the alcohol research can now be entered into profitably. The investigation undertaken by Professor Miles is a completion and elaboration of section I of the psychological part of the "Tentative plan for a proposed investigation into the physiological action of ethyl alcohol in man."

Respiration in oxygen-rich atmospheres.—In many of the forms of respiration apparatus used in this Laboratory, the percentage of oxygen in the air inspired by the animal is rarely that of normal air. This fact has led to an extended investigation on the influence of the inhalation of atmospheres rich in oxygen. The effect upon human subjects has been extensively studied in short experiments by Mr. Higgins, of the Laboratory staff, and no material alteration has been found in the total amount of oxygen absorbed or carbon dioxide produced, even when an atmosphere containing 95 per cent of oxygen has been inhaled for periods of 15 minutes. As it is obviously impossible to use human subjects for very long periods, a series of experiments has been carried out with rabbits, employing a special form of respiration apparatus and chamber, the preliminary experiments being made in association with Dr. Carl Tigerstedt. This research has been steadily continued throughout the experimental year with the active cooperation of Professor Howard T. Karsner, of the Harvard Medical School, whose studies of the subjects, after a long sojourn in the oxygen-rich atmosphere, lend great value to the research. In these experiments the rabbit is placed inside the chamber in an atmosphere which is maintained at a high percentage of oxygen for several days; the rabbit is then killed and a complete study of all its tissues made. The results should throw much light upon the clinical use of oxygen.

Insensible perspiration and muscular activity of infants.—In conjunction with Dr. H. W. Stevens, of the Massachusetts General Hospital, and Dr. Fritz B. Talbot, a series of observations was made upon the insensible perspiration of infants. A simultaneous graphic record of the muscular activity of the infant was likewise made by means of a modified form of the so-called "ward crib recorder." With this apparatus, the infant lies in a crib suspended at one end on a knife-edge and at the other by a stout spring; the vertical movements of the crib due to the muscular activity of the child are summed up by a work-adder arrangement and the total effective movement for a given period of 12 to 24 hours is thereby recorded. When the sum of muscular activity is compared with the actual loss in weight of the infant due to insensible perspiration, an interesting relationship may be established.

Photographic registration of pulse-rate.—The great significance of the pulse-rate as an index of total metabolism, which has frequently been emphasized in publications from this Laboratory, has led to making arrangements for registering photographically the pulse-rates of practically all subjects, both human and animal, in experiments carried on here. The photographic registration apparatus now installed include the Cambridge string galvanometer with its photographic appliances, the Thoma oscillograph, the various forms of smaller string galvanometers, and the electrically-driven kymographs. These have made possible an important series of photographic registrations which could not heretofore be obtained—for example, the pulse-rate of a man walking at the rate of 80 meters per minute in the experiment on the treadmill. By the use of a lead-covered cable, extending some 300 or 400 meters through the tunnel connecting the various neighboring buildings, it has likewise been possible for us to record photographically (and with a high degree of accuracy) the pulse-rate of a premature infant in one of the wards of the Infants' Hospital. A study of the pulse-rate of premature infants throughout long periods of the day is planned for the immediate future.

Calorimeter for infants and small animals.—A fundamental research into the conditions most suitable for measuring the heat output of infants and small animals is being carried on in cooperation with Mr. E. H. Lange. Considerable progress has been made towards perfecting an instrument of great sensitiveness and small mass.

Respiration chamber for pathological cases.—Many pathological subjects find difficulty in normal respiration with respiratory appliances fitted to either the nose or the mouth; hence the need has long been felt for a respiration chamber of a type which can be used in hospitals and clinics and in which there may be free and normal breathing. A special form of chamber for use in connection with the Nutrition Laboratory type of respiration apparatus is now being developed. With this chamber it will be possible to control the measurement of the respiratory exchange by means of at least three entirely independent methods. The importance of this control with subjects presenting abnormal metabolism can not be overestimated.

Calibration of the Krogh bicycle ergometer.—A most ingenious form of bicycle ergometer, based upon the electric-brake principle, has been devised by Professor August Krogh, of Copenhagen. One of these bicycle ergometers has been purchased and a series of calibrations made with it to establish a constant. For this purpose the ergometer was mounted in the chair calorimeter and rotated by an electric motor and gear from the outside. The investigation is still in progress, with the cooperation of Mr. L. E. Emmes.

Translation of Russian literature.—The accumulation of important Russian monographs in my visits to Russia and the continual receipt

of such material has again emphasized the necessity for maintaining a translator. Several books and dissertations bearing directly upon the more important problems of the Laboratory have been translated during the past year and such work will be continued. It is of interest to record permanently here the translations thus far made since the establishment of the Nutrition Laboratory in 1907:

P. P. Awrorow:
Measurements of metabolism and energy production of the organism during complete fasting. From the Laboratory of General Pathology of Professor Albitsky. Dissertation, St. Petersburg, 1900, 192 pp.

P. P. von Betlingk:
On the modification of the chemical composition of the organism in starvation. From the Department of General Pathology of the Imperial Institute of Experimental Medicine. Archiv of Biological Sciences, St. Petersburg, 1897, 6, part 2, pp. 387–408.

J. A. Kagan:
Intermittent acute starvation. From the Laboratory of General Experimental Pathology of Professor V. V. Pashutin. St. Petersburg. Russian Medicine, Nos. 26 and 27, 1886, pp. 1–16.

E. Kartaschefsky:
The influence of the lack of oxygen upon the exchange of matter and heat production in the animal organism. From the Imperial Military Medical Academy, Dissertation No. 42, St. Petersburg, 1906, 271 pp.
On the influence of the surrounding temperature upon animals in an atmosphere poor in oxygen. From the Laboratory of General Pathology, Professor Albitsky. St. Petersburg. Reports of the Imperial Military Medical Academy, 1908, 16, pp. 259–285.
Rôle of fats and carbohydrates in the nutrition of the organism. Reports of the Imperial Military Medical Academy. St. Petersburg, 1911, 22, 50 pp.

A. Likhatscheff and P. P. Awrorow:
The influence of alcohol on the heat and gas exchange in man. From the General Pathological Laboratory of Professor Albitsky, St. Petersburg, 1882, 32 pp.
Investigations of gas and heat exchange in fevers. Reports of the Imperial Military Medical Academy. St. Petersburg, 1902, 5, Nos. 3 and 4, 64 pp.

V. V. Pashutin:
A course of general and experimental pathology. (Pathological physiology.) St. Petersburg, 1902, vol. 2, part 1, pp. 1 to 799, on inanition. The translation has been typewritten, manifolded, and bound, and copies are deposited in the Library of the Surgeon General's Office in Washington, the New York Public Library, and the John Crerar Library in Chicago.

V. Posajnyi:
The gaseous exchange in fasting dogs. From the Laboratory of General and Experimental Pathology of Professor Pashutin. Dissertation, St. Petersburg, 1886, 102 pp.

S. N. Predtetchenski:
Metabolism of matter in the organism under the influence of an artificially produced rise of body-temperature. From the Laboratory of General Pathology of Professor Albitsky. Dissertation, St. Petersburg, 1901, 156 pp.

A. Sadovyen:
Metabolism in fasting. Pub. of Russian Soc. Gen. Hygiene, St. Petersburg, 1887–88, 12.

M. L. Sagalow:
Skin perspiration of normal young children. From the Children's Clinic of the Imperial Military Medical Academy. St. Petersburg, 1907, 58 pp.

Skoritchenko:
An investigation of some factors of starvation. 1882, pp. 175–233. (Place of publication not known.)

A. I. Sytcheff:
Measurement of volume and surface of children of varying ages. From the Clinic of Children's Diseases of Professor N. P. Gundobin. St. Petersburg, 1902, 98 pp.

I. J. Tuvim:
The effect of taking water internally on the respiratory exchange of animals. From the Laboratory of General and Experimental Pathology of Professor Pashutin. Dissertation, St. Petersburg, 1889, 90 pp.

T. N. Viazemsky:
A bibliography on the question of alcoholism. Moscow, 1909, 1st ed., part 1, 54 pp.

PUBLICATIONS.

The following publications have been issued during the year:

(1) The influence of food, posture, and other factors on the alveolar carbon-dioxide tension in man. Harold L. Higgins. Am. Jour. Physiol., 34, p. 114 (1914).

The alveolar carbon-dioxide tension as an index of the degree of acidosis has become of considerable importance in recent years, especially in cases of diabetes. This paper deals with variations which normally may occur in the alveolar carbon-dioxide tension, under conditions ordinarily met with, especially as to the influence of different body positions and the taking of food; facts were found which may be of value for interpreting the alveolar carbon-dioxide data secured with diabetics. The data obtained also offer material bearing on the physiology of respiration and the respiratory center, especially in its relation to the vaso-motor center.

It was found that:

(1) The alveolar carbon-dioxide tension rose after the taking of food and remained high so long as food was in active digestion.

(2) The alveolar carbon-dioxide tension was higher with a relaxed position than with an erect position. Thus, it was higher when the subject was sitting than when standing and still higher when lying down.

(3) Coffee, without food, caused a rise of the alveolar carbon-dioxide tension. These changes seem to be due to some factor other than (or in addition to) that of hydrogen-ion concentration of the blood affecting the respiratory center.

(2) The gaseous metabolism of infants with special reference to its relation to pulse-rate and muscular activity. Francis G. Benedict and Fritz B. Talbot. Publication No. 201, Carnegie Institution of Washington (1914).

A complete historical review of all the literature on the gaseous exchange and calorimetry of infants is followed by a presentation of several important problems in this field. A respiration apparatus, measuring simultaneously carbon-dioxide production and oxygen consumption and provided with a sensitive arrangement for registering automatically and graphically the slightest body movement, was used to study 37 infants during approximately 800 periods of observation. Continuous records of the pulse-rate and a graphic representation of the degree of muscular repose enabled many important correlations with the respiratory studies.

A series of 12-hour continuous pulse records, accompanied by ocular observations of the degree of repose, showed a sudden and considerable increase of the pulse-rate with crying or nursing and a rapid return to the low level with cessation of crying and feeding.

A comparison of the pulse-rate with the muscular activity as determined by the kymograph records of a swinging crib showed invariably a close agreement. The metabolism also increased or decreased as the pulse-rate and activity increased or decreased. Distinct evidence of an increased pulse-rate and metabolism independent of external activity was interpreted as being an indication of internal work and suggested the pulse-rate as an index of this internal work.

Particular stress was laid upon a comparative study of the basal metabolism of the infants, *i. e.*, the metabolism during complete muscular repose as shown by the kymograph records. Under these conditions it was found that while, in general, the smaller infants had the smaller total metabolism, there were sufficient striking exceptions to prevent the formulation of a definite law. Similarly, there was no uniformity in the metabolism per kilogram of body-

weight, although with "normal" children the plotted chart gave indications of an approximately regular line. As many of the infants were under weight, the total metabolism was compared with the normal weight for the age, also the expected weight computed from the birth-weight and normal growth thereafter, but no approach to uniformity or regularity was apparent.

A discussion of the supposed relationship between body-surface and metabolism and a critique of the methods used for measuring body-surface introduce the discussion of the values found with these infants. No relationship was found between the age of the infants and the heat produced per square meter of body-surface, nor could any relationship be noted between the heat-production per square meter of body-surface and the actual body-weight, the normal weight for the age, or the expected body-weight.

Evidence secured with normal and atrophic infants of different ages and weights is presented to show that the active mass of protoplasmic tissue determines the heat-production. This active mass of protoplasmic tissue may be stimulated to a greater or less cellular activity, the intensity of the stimulus being indicated by the pulse-rate.

(3) Studies in the respiratory exchange of infants. Francis G. Benedict and Fritz B. Talbot. Am. Jour. Diseases of Children, 8, p. 1 (1914).

The results reported in Publication No. 201 of the Carnegie Institution of Washington are given in this paper and further elaborated by the addition of data more recently obtained, including especially that for numerous new-born infants.

(4) The basal gaseous metabolism of normal men and women. Francis G. Benedict, Louis E. Emmes, Paul Roth, and H. Monmouth Smith. Jour. Biol. Chem., 18, p. 139 (1914).

A large number of experiments on so-called "normal" individuals have been made during the past seven years for the purpose of comparison with pathological and other subjects. The results of these observations which, at the time of printing, had been obtained with 89 men and 68 women, are presented in this paper in tabular form, the data including the age of the subjects, the number of days under observation, the number of experimental periods used in averaging the results, the body-weight without clothing, the height, the carbon-dioxide production and oxygen consumption per minute and per kilogram per minute, the pulse-rate, and the total heat computed for 24 hours per kilogram of body-weight and per square meter of body-surface. Normal individuals are here assumed to be "people in presumably good health." This collection of data represents a preliminary attempt to provide a metabolism standard for people of different heights, weights, ages, and sex.

(5) A study of prolonged fasting. Francis G. Benedict. Publication No. 203, Carnegie Institution of Washington (1914).

In the spring of 1912 an experiment was made on a subject, A. L., who subsisted for 31 days without food, drinking during that period only 750 c.c. of distilled water per day. Observations were also made for 4 days prior to the fast and imperfect observations for 3 days subsequent to it. The main object of the investigation was to determine simultaneously as many factors in the physiology of the subject as possible.

The research included physical examinations by a physician, accompanied by photographic studies and careful anthropometric measurements; records of the body-weight, rectal temperature, pulse-rate, and blood pressure; a

complete daily examination of the blood; and a study of the mechanics of respiration, including the ventilation of the lungs, the respiration-rate, and the alveolar air. Records of subjective impressions and of the subject's mental attitude toward the fast were kept, together with a series of psychological tests. Observations were also made of the intestinal flora and the excretion through the skin. A complete chemical examination of the urine was carried out by modern methods, which included determinations of the various nitrogenous compounds, acid and basic radicles, carbon and energy, and the microscopy of the urine. An extended study was made of the respiratory exchange in which both the respiration apparatus and the respiration calorimeter were used, this including the study of the influence of various factors upon the respiratory exchange, such as the work of writing, of breathing oxygen-rich atmospheres, and the conditions of sleeping and waking. The elimination of water through the lungs and skin was also determined. From these data important deductions regarding the total katabolism per 24 hours, the character of the katabolism, the loss of water from the body, the loss of original body-substance, and the total energy loss were drawn.

The observations were carried out chiefly by the laboratory staff and with the cooperation of Drs. W. G. Anderson, J. E. Ash, H. W. Goodall, E. C. Kendall, H. L. Langfeld, and E. E. Southard. It is impossible in this brief abstract to comment intelligently upon the results, which are extensive and should throw much light upon the relationship between inanition and disease.

DEPARTMENT OF TERRESTRIAL MAGNETISM.*

L. A. Bauer, Director.

GENERAL SUMMARY.

Possibly the event of prime importance, during the fiscal year November 1, 1913, to October 31, 1914, was the removal of the Department, at the end of February 1914, to its new and permanent home. It is of added interest that this removal occurred just as the Department was rounding out its first decade of existence. Established on April 1, 1904, and housed in rented quarters ever since, where it was impossible to secure all the required facilities, it could thus on April 1, 1914, enter on its eleventh year under auspicious circumstances and with renewed life and vigor.

It may be worth while to summarize briefly what this Department, with the funds provided from time to time and the cordial assistance received, has been enabled to accomplish during the period April 1, 1904, to April 1, 1914. Two vessels (the *Galilee*, 1905–1908; the *Carnegie*, 1909–1913) have been engaged in ocean magnetic surveys, the aggregate length of the cruises being nearly 161,000 miles, covering all the oceans from about 50° north to 50° south; 38 land magnetic survey expeditions have been sent out in 103 countries, extending from about 80° north to 55° south, the magnetic observations having been made at about 2,500 points, requiring an amount of travel (generally in more or less unexplored or difficult regions) aggregating about 800,000 miles; the total amount of travel involved in both the ocean and the land work in execution of the project of a general magnetic survey of the globe approximates thus 1,000,000 miles (about 40 times the Earth's circumference). Four Arctic and Antarctic expeditions have been assisted, the necessary instrumental outfits having been loaned and the requisite training and directions given to the observers; at 29 of the chief magnetic observatories, and also at a number of secondary ones, the magnetic standards of the Department have been compared with those in use at the respective observatories, thus making it possible to reduce to the same standard magnetic data obtained the world over. A non-magnetic yacht, *Carnegie*, the first vessel specially designed for ocean magnetic surveys, was built in 1909 and has been now five years in commission, during which time she has circumnavigated the globe and has sailed over all the chief lanes of ocean travel with practically no mishap, the aggregate length of her cruises up to

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Headquarters and Laboratory of Department of Terrestrial Magnetism at Washington.

December 31, 1913, being about 100,000 miles. A specially designed office and laboratory building, containing 44 rooms, was erected during the period May 1913 to February 1914. Seven new instruments, for use in magnetic surveys at sea and on land, have been designed and chiefly constructed in the Department's own instrument shop; with the methods and appliances introduced, an accuracy has been achieved in ocean work almost comparable with that on land; about 125 articles and publications by various members of the investigational staff have appeared; the magnetic data of interest and importance to mariners have been made known with a promptness heretofore impossible; in fact, the data have usually been available to the leading hydrographic establishments within two to four months after the observations were made at sea.[1] A variety of investigations (theoretical, observational, and experimental) have been made, the chief results of which either have already been published, or can be within the next two years; last, but not least, a number of men have now received the requisite training and experience to assure continued successful progress of the work of the Department.

To bring the preceding summary of work to the date October 31, 1914, there should be included the chief operations and results described in the following pages. It must be a matter of congratulation that so much of the magnetic survey work could be completed before the intervening of such serious interruptions as must necessarily follow with a continuance of the inter-European war.

MAGNETIC SURVEY OF THE OCEANS.

The circumnavigation cruise of the *Carnegie*, as already stated in the previous report, was successfully completed with the return of the vessel to Brooklyn on December 19, 1913. During the period February to June 1914, all necessary repairs were made. On June 8, 1914, the *Carnegie* sailed away again from Brooklyn, on her third cruise, this time in the North Atlantic, and under command of Mr. J. P. Ault, Mr. Peters having been placed in charge of the important expedition to Hudson Bay mentioned below.

The *Carnegie* arrived at Hammerfest, Norway, on July 3, after a very successful trip. The shore and harbor work having been completed, she left Hammerfest on July 25, bound for Reykjavik, Iceland, reaching, during the trip, under sail alone, the remarkably high latitude of 79° 52′ north, in the East Greenland Sea and off the northwest coast

[1]For example, the values of the magnetic declination observed aboard the *Carnegie* from Long Island Sound to Hammerfest, June 10 to July 2, 1914, were printed in the issue of the Journal Terrestrial Magnetism, which appeared on September 1, 1914. The values on the portion of the cruise, Hammerfest, Spitsbergen, Iceland, July 26 to August 23, 1914, were received at Washington on September 21, ready to be sent to the printer.

of Spitzbergen.[1] The *Carnegie* arrived at Reykjavik on August 24 and, after completing her shore and harbor work, she left on September 15 for Brooklyn, where she arrived on October 21. The total length of this cruise was about 10,600 miles. The control observations made at the intersection of the tracks of the present cruise with those of the 1909 cruise have once more demonstrated the high accuracy reached with the appliances and methods used aboard the *Carnegie*.[2] The *Carnegie* will next be fitted out for a cruise of about two years, during 1915–1916, chiefly in extreme southern latitudes, 50° to 75°. Plate No. 7 shows the tracks followed on the third, or 1914, cruise.

In addition to the usual magnetic observations, special attention has been paid also on this cruise to work in atmospheric electricity and radioactivity. New methods and instrumental appliances have been introduced, as based on the experience gained by the observers during the past cruises and the theoretical and experimental work of Dr. W. F. G. Swann in the Department laboratory at Washington. Under "Investigational Work in Washington" the results in atmospheric electricity obtained on the previous cruises are briefly stated.

For several years plans have been made for an expedition to Hudson Bay to supplement the data obtained by the land expeditions sent out by the Department. Owing to the heavy ice-conditions likely to be encountered, it was not safe to undertake the expedition, as would have been desirable, in the *Carnegie*, which was not built for work in the Arctic regions. Accordingly a gasoline schooner, the *George B. Cluett*, was chartered from the International Grenfell Association for three months. The charter included the captain and other sailing personnel, and all subsistence, including the subsistence of the observing party, consisting of Mr. W. J. Peters, in charge, and Observer D. W. Berky. On account of the heavy ice along the Labrador coast this year, it was not possible for the expedition to leave Battle Harbor, Labrador, until July 31. Owing to the unusual ice-conditions, the entry into Hudson Bay was delayed until September 2. However, valuable observations were secured along the entire route, and the expedition returned to Battle Harbor on October 3.

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[1]On August 21, the day of the solar eclipse, clear weather was encountered, the vessel being in latitude 63° 24′.5 north and longitude 14° 32′.5 west. The times of contact were observed, some photographs with small cameras were secured, and atmospheric-electric observations were made.

[2]From the results of the present cruise it is seen that, on the average, the existing magnetic charts show a west compass direction (west magnetic declination) too small, by about 1° to 3°, according to the chart, thus again indicating that erroneous corrections on account of secular changes in the compass direction have been used.

MAGNETIC SURVEY OF LAND AREAS.

Very satisfactory progress has been made by the various land expeditions, though, during the period since the outbreak of the inter-European war, some changes in plans became necessary and increased expense ensued. The chief expeditions were:

1. Coastal trips by Observer W. F. Wallis in Tripolitana and Egypt and interior trips in Abyssinia.
2. Coastal trips by Observer H. E. Sawyer in middle-western Africa and extensive interior trips in Nigeria.
3. Extensive interior trip in the Belgian Congo by Observer D. M. Wise.
4. Practical completion of the remaining portion of the general magnetic survey of Australia, necessitating difficult and lengthy interior trips by camel caravan and by automobile, by Observers E. Kidson (chief of party), W. C. Parkinson, F. Brown, and A. L. Kennedy. Some work was also done in the outlying islands.
5. The complete crossing from west to east of Peru and Bolivia, via Arica, La Paz, and Corumbá; thence north along the Guapore and Madeira Rivers to the Amazon River, by Observer H. R. Schmitt.
6. Completion of an expedition by Observer A. D. Power, mainly by canoes, in Venezuela. Colombia, Ecuador, and Brazil, going up the Meta River to Bogotá, Colombia, and descending the Putamayo River to the Amazon, thence along the latter river to Manaos, Brasil.

INVESTIGATIONAL WORK IN WASHINGTON.

RESEARCH BUILDINGS.

The permanent facilities provided for the investigational and administrative work at Washington at the close of the fiscal year are as follows:

1. A site of 7.4 acres, admirably located amidst rural surroundings, in the District of Columbia, in close proximity to the extensive National Rock Creek Park and sufficiently removed from industrial disturbing influences.
2. A commodious fire-proof building, solidly built of reinforced concrete and brick, containing the Director's headquarters and working-rooms for the staff, library and archives, physical laboratory, instrument shop, testing laboratories, and storage rooms. The main building consists of a sub-basement, a basement, two floors, a spacious and well-lighted attic, and a specially constructed roof with observation deck. It is 102 feet long, 52 feet wide, 49 feet from the ground to the roof, and 62 feet from the foundations of the sub-basement to the roof. Its erection was begun in May 1913, and it was completed on February 14, 1914.
3. A non-magnetic building (standardizing magnetic observatory), 28 feet wide and 58 feet long, with a bay on the east side 21.5 feet long and 9.5 feet wide, in order to provide the necessary facilities for tests and researches requiring a non-magnetic structure. This observatory is sufficiently removed from the main building to be practically beyond its disturbing influence.

4. Two accessory huts used formerly for standardizing and testing magnetic instruments, but now available for researches in cosmophysical subjects. With the initial equipment, the total cost of 1, 2, 3, and 4 approximates $128,000. The magnetic observatory (3) was erected in 1914 by the Department itself, under the direct supervision of Mr. J. A. Fleming.

It is furthermore hoped that in 1915 a tower about 80 feet high may be erected, on which a hut (12 by 12 feet) may be built to house atmospheric-electric instruments.

Thus the Department of Terrestrial Magnetism is rapidly acquiring exceptional facilities for its varied work, both in the field and allied subjects. With the expected near completion of its first great observational task—the general magnetic survey of the Earth—the time is ripe to take the initial steps for other world-wide projects outlined in the program of work of this Department (see Year Book No. 2, for 1903, p. 204), for example, *International observations of the variations of the Earth's magnetism.* This requires the establishment and maintenance for a term of years of observatories at certain fixed points, the location of which is to be determined with reference to the existing institutions, so as not to duplicate but rather to supplement in the required effective manner.

With the end in view just stated, preliminary examinations of sites have already been made in the past by our various land expeditions. Battle Harbor, Labrador, or vicinity would be a very suitable location for an observatory such as contemplated. Polar lights occur here frequently and the opportunities for combined research in terrestrial magnetism and terrestrial electricity (polar lights, telluric electric currents, and atmospheric electricity) would be excellent. The Bermudas and Bahamas would also afford good sites, but cosmophysical observatories require supplementing, especially in the Southern Hemisphere. Should interruptions occur in the prosecution of the magnetic-survey work in 1915, because of war conditions, it would be desirable to inaugurate the field-observatory work. It may be mentioned that the establishment of such observatories is also urgent for supplying the data needed in the reduction of the magnetic-survey work to a common epoch and to keep our proposed world magnetic charts corrected to date.

The existing observatories are insufficient in number and are inadequately distributed. For example, about half of the total number of magnetic observatories are located in Europe and only about 15 per cent of them are in the Southern Hemisphere. In brief, the present distribution of magnetic observatories is inter-European rather than international, as is required for the successful solution of the great problems concerning the causes of such world-wide phenomena as, for example, the diurnal variation of the magnetic needle; magnetic storms which in a moment's time may derange the entire magnetization of

the Earth by 20 per cent; electric storms which disturb instantly telegraphic and telephonic communications and give rise to other marked disturbances.

PUBLICATION WORK.

The manuscript was completed for volume 2, Researches of the Department of Terrestrial Magnetism, bearing the title "Land Magnetic Observations 1911 to 1913 and Reports on Special Researches, by L. A. Bauer and J. A. Fleming." This volume contains the results of the magnetic observations made by the land expeditions during the three years 1911–1913, at 978 stations distributed over 57 countries and island-groups, in all parts of the Earth. The previous volume contained the results of the land magnetic observations 1905–1910. The publication of the land results has thus been brought up to 1914.

The manuscript for volume 3, to contain the final results of all the ocean work, 1905–1913, is in good state of progress, and it is hoped that the volume may appear in 1915.

The reports on special researches given, as mentioned above, in volume 2 comprise: Description of research buildings of the Department of Terrestrial Magnetism, by L. A. Bauer and J. A. Fleming; magnetic inspection trip and observations during total solar eclipse of April 28, 1911, at Manua, Samoa, by L. A. Bauer; results of international comparisons of magnetic standards, 1905–1913, by L. A. Bauer and J. A. Fleming.

There have also appeared in various journals during the year 15 articles, and several are in preparation, by Messrs. Armstrong, Ault, Bauer, Duvall, Hewlett, Kidson, Peters, and Swann; the subjects covered are atmospheric electricity, general physics, mathematics (methods of seeking hidden periodicities), solar and terrestrial magnetism. (See Bibliography, pages 40–49, and Abstracts.)

TERRESTRIAL MAGNETISM.

Besides the publication work already mentioned and the instrumental work described below, investigations of various kinds are in progress. The interesting question as to the cause of the observed equatorial increase in the intensity of the Earth's apparent magnetization, as announced in the report for the fiscal year 1911–1912, has received renewed attention. The fact that there is such an increase in the equatorial regions has now been verified in various ways.

The Director has furthermore completed a preliminary study, the results of which were presented before the recent meeting of the Astronomical and Astrophysical Society, entitled "On the solar radiation and terrestrial magnetism."[1]

[1]Published in Terrestrial Magnetism, September 1914, pp. 113–125.

From a preliminary investigation in 1909, it was found that an increase in solar activity, as judged by sun-spot frequency, was in general accompanied by a decrease in the so-called local magnetic constant which, under certain assumptions, is proportional to the intensity of the magnetization of the Earth. The present investigation examines into the possibility of a relationship between fluctuations in the solar radiation and certain changes of the Earth's magnetism. Use was made for this purpose of Abbot's extensive series of solar-constant values.

As a provisional result, it was found that for a change of 10 per cent, such as may be observed in the value of the solar constant, there is apparently a change in the magnetic constant, above referred to, of about 0.03 per cent of its value, decreased magnetic constant corresponding to increased solar constant. The effect is most pronounced in the sun-lit portion of the globe, and hence may vary according to local apparent time, just as a certain class of magnetic disturbances is known to do. It is furthermore of interest, in this connection, to recall the class of magnetic disturbances which it was found did not occur simultaneously over the globe, but, instead, each time were recorded only at the observatories in the daylight zone.

While the discovery that the Earth is not the only rotating celestial body enveloped by a magnetic field may assist in solving the vexed problem as to the origin of planetary magnetism in general, possibly especial progress may be expected from the discovery of the agencies responsible for the space and time variations in the particular magnetic field under consideration. Each body may present characteristics of its magnetic field having no counterpart elsewhere. Accordingly the Department studies are at present directed mainly to the study of the variations of the Earth's magnetic field and of the causes which make it depart from the simple type generally postulated by theories. It is believed that a long step forward has been taken toward the discovery of the origin of the Earth's magnetism when once we thoroughly understand what causes it to vary in the surprising manner shown, for example, by the secular or long-period changes, by magnetic storms, by the diurnal variation, etc. However, before long these studies may be supplemented by certain laboratory investigations.

An investigation pertaining to the variations of the Earth's magnetism was made during the past summer by Messrs. G. N. Armstrong[1] and C. R. Duvall. The title of this research is "On the study of methods of seeking hidden periodicities, with some applications to magnetic and sun-spot data." The main part of the work was devoted to recurring-series methods, which were first investigated by Lagrange in 1772; also a brief study of some other methods was made. In his

[1]Associated with the Department as mathematician, June 26–September 10, 1914.

dissertation for the doctorate degree at the Technische Hochschule at Munich, in 1913, Dr. Armstrong had developed the methods of Lagrange with numerous applications, first, to computed values of an assumed periodic function, for the purpose of testing the powers and limitations of the method, and, second, to observational data of suspected periodicity. A preliminary application of the method was made to magnetic data (diurnal range of the magnetic declination at three European stations) during the period 1841 to 1910, as also (chiefly for the same period) to the Wolf-Wolfer sun-spot numbers.

For the magnetic data three periods, respectively of about 11.4, 22, and 70 years, were found. Periods of about the same length were disclosed by the sun-spot data. As in the present work the data were combined into 5-year means, shorter periods than the one of 11.4 years could hardly be detected. The investigation is being continued.

ATMOSPHERIC ELECTRICITY.

Notable progress, it is believed, has been achieved by the Department, during the present year, by the theoretical and experimental researches of Dr. W. F. G. Swann. In the experimental work he was assisted by Dr. C. W. Hewlett and Mr. H. F. Johnston. Five articles by Dr. Swann (see pages 328 and 332) have appeared, in which new points of theory were brought out, serious errors in certain instruments were made known, and improved methods and instruments were devised. As a result, considerable improvement has been made in the work in atmospheric electricity aboard the *Carnegie*, on her third cruise.

It is now deemed worth while to expand the work of the Department in this subject in two directions: (*a*) continuous observations, by self-recording means, in atmospheric electricity and radioactivity, at the Department's laboratory in Washington and at such observatories elsewhere as the Department may be able to establish in the near future; (*b*) a general electric survey of the globe, implying observations at points distributed over the Earth's surface, somewhat as in a magnetic survey.

Probably the late Professor Rowland was one of the first, in his address before the Congress of Electricians, held at Paris, September 1881, to point out the need, in atmospheric electricity, "of a series of general and accurate experiments performed simultaneously on a portion of the Earth's surface as extended as possible."[1] He says that "the principal aim of scientific investigation is to be able to understand more completely the laws of nature, and we generally succeed in doing this by bringing together observation and theory." On Professor Rowland's motion, the Congress resolved "that an international commission be charged with determining the precise methods of observation

[1]Physical Papers of Henry A. Rowland, Baltimore, 1902, p. 212 *et seq.*

for atmospheric electricity, in order to generalize this study on the surface of the globe."

Unfortunately, in the past, the observations in atmospheric electricity have often been found to be counterfeits of nature because of the errors inherent in the instruments and methods used. Accordingly the much-desired discovery of nature's laws, by "bringing together observation and theory," has not been brought about in the measure desired. None of the proposals for a general electric survey of thf Earth which have been made repeatedly to learned academies, one oe the last having been presented to the International Association of Academies, has been put into effect, doubtless because of the discouraging experiences encountered. In spite of the vast work already done by notable investigators, we still have no generally accepted theory of the origin of atmospheric electricity, not even as yet a satisfactory explanation of a thunderstorm.

Probably one of the most important of recent contributions to the observational data is the summary of observations obtained on the cruises of the *Galilee* and the *Carnegie*. A report giving the results up to the end of 1913, obtained by the Department observers and others, was prepared by Dr. Hewlett and published in the September (1914) issue of Terrestrial Magnetism and Atmospheric Electricity. The observations comprised, in addition to the usual meteorological measurements, those of the potential gradient, atmospheric conductivity, and radioactive content of the atmosphere. Perhaps the most important result is a confirmation of the somewhat striking phenomenon that, while the conductivity over the ocean is, on the average, at least as great as over land, the radioactive content is much smaller. The values of the potential gradient obtained at sea were of the same order of magnitude as those on land. (See pp. 324–327).

INSTRUMENTAL WORK.

Four new universal magnetic instruments of the type which combines magnetometer and earth inductor, with the accompanying galvanometer, have been designed and constructed in the Department's shop, under Mr. Fleming's superintendence, and have thus far proved very satisfactory. At the end of the year another instrument of this type is under construction; also one of the type combining magnetometer and theodolite. Other miscellaneous instrumental matters have likewise received attention.

Some instruments for observations in atmospheric electricity on land and at sea have been constructed under Dr. Swann's direction.

On April 24–25, the Department took part in the exhibit of instruments at the Bureau of Standards in connection with the meeting of the American Physical Society. Several instruments of its own design and make, as well as some new laboratory instruments, were exhibited.

MISCELLANEOUS.

Desired preparations have been made for the proposed exhibit in the Administration Building next December and at the Panama Exposition. Besides some of the typical instruments of the Department's design and make, there will be photographs, a globe, and an admirably executed 4-foot model of the *Carnegie*, made by the Boucher Manufacturing Company of New York, upon special order from the Institution.

In conclusion, grateful acknowledgment should be made of the many courtesies received by our various field parties from government officials and diplomatic officers. Often special arrangements were made, military escorts or traveling facilities being provided and most helpful letters of introduction being supplied.

DETAILS OF OBSERVATIONAL WORK.

OCEAN WORK.

On November 1 the *Carnegie* was en route from Falmouth, England, to New York. On account of heavy weather she put in at New London, Connecticut, on December 14, and was towed to Greenport on December 15. After reoccupying the repeat stations at Greenport and Shelter Island, the party left for Brooklyn on December 18, and the vessel was berthed at Beard's yacht basin, Brooklyn, on December 19. The Director inspected the vessel here and conferred with Captain W. J. Peters regarding the repair work required after the three years' continuous cruise of the *Carnegie*. After a careful consideration of the various proposals received, it was decided to have the necessary repairs made by Tietjen & Lang, of Hoboken, New Jersey, under the immediate supervision of Mr. Peters, as the representative of the Department. The *Carnegie* was accordingly towed to the Tietjen & Lang shipyard on February 24. The repairs to the hull, required by the dry rotting of timbers which had set in, were completed on April 10, and the vessel was then towed back to Beard's yacht basin. The stone ballast, previously used, was replaced by lead ballast, and other repairs and alterations were made in accordance with the experience gained on the previous cruises. On April 6 Mr. R. E. Storm was engaged as mechanical engineer. We were fortunate in being able to avail ourselves also, for a few days, of the expert assistance of Mr. C. D. Smith, of the United States Bureau of Mines. The refrigerating plant and oil engine were overhauled and some minor, tentative changes were made in the producer gas engine.

Meanwhile the plans had been made for the third cruise of the *Carnegie*, to be this time wholly in the northern Atlantic Ocean. The command of the vessel was transferred on June 1 from Mr. Peters to Mr. J. P. Ault, Mr. Peters having been placed in charge of the important expedition to Hudson Bay, an account of which is given below.

Dr. W. F. G. Swann, assisted by Dr. C. W. Hewlett and Observer Johnston, made the final installations for the atmospheric-electric work and prepared the necessary directions.

When the Director had made his inspection of the vessel and had given the final instructions regarding the cruise and the program of work, the *Carnegie* left Brooklyn, on June 8, direct for Hammerfest, Norway, with the following personnel aboard: J. P. Ault, magnetician and in command of vessel; Dr. H. M. W. Edmonds, magnetician and surgeon; Observers H. F. Johnston and I. A. Luke; N. Meisenhelter, meteorological observer and clerk; R. E. Storm, mechanical engineer; Watch Officers J. Sahlberg, J. Johnson, and T. Pedersen; Mechanic C. Heckendorn; 8 seamen, 2 cooks, and 2 cabin boys; 22 persons in all. Mr. Martin Clausen, who had served faithfully, first as second and later as first watch officer on the previous cruises, on May 17, during shore leave, unfortunately met with an accident and died on May 24. On May 27 Mr. John Sahlberg was appointed first watch officer in his stead.

The *Carnegie* followed a course from Brooklyn practically due east along the parallel of 41° north to about 53° west longitude, and thence practically in a direct line to Hammerfest. A landfall was made in the vicinity of the Faeroes on June 27. Hammerfest was reached on July 3, after a cruise of 4,182 nautical miles. In addition to the usual stations occupied at Hammerfest for the purpose of determining the instrumental constants, observations were secured in the neighborhood at five additional stations for the purpose of selecting a suitable place in the harbor to "swing" the vessel, and thus test anew the absence of ship deviations at the mounts of the magnetic instruments. "Swings" were secured on July 15, 16, and 18, with satisfactory results for both horizontal intensity and inclination, as also for declination, due account being taken of the small horizontal intensity (0.1 C. G. S.) at this high magnetic latitude. These tests showed once more, as in the previous cruises, that there are no deviations of sufficient magnitude to be taken into account. On July 25 the *Carnegie* left Hammerfest, bound this time for Reykjavik, Iceland, Captain Ault's instructions being to proceed as far north as ice-conditions permitted, without endangering the safety of the vessel.

The following interesting extract is taken from Captain Ault's report, dated Reykjavik, August 27, 1914:

"After leaving Hammerfest it was planned to make a short trip into the Barents Sea towards Nova Zembla, but, head winds being encountered, the course was shaped for Spitzbergen. We were becalmed 2 days off Bear Island, after which we had fair winds until July 31, when we sighted ice about 30 miles south of South Cape, the southernmost point of Spitzbergen. A few hours later we were headed off by the solid ice-pack, but we could see the western edge of the pack and knew that by standing to the westward we could

clear it. This flow did not extend far into the sea west of Spitzbergen, it having drifted down from Stor Fjord to the eastward of Spitzbergen. Standing to the westward, we cleared the ice, and being favored with fair winds and good weather, continued northward.

"On August 2, all plans were made to swing ship the next day north of latitude 80°, the engine being in running order. That night the southwesterly wind increased to a gale, making it necessary for us to heave-to and try to get south, as the solid polar ice-pack was only about 50 miles to the northward. *Our farthest north, therefore, was latitude 79° 52'.3.* After 4 days of head winds we again had favorable winds, but for 4 days we saw nothing of the Sun, and consequently secured no declination observations. Off the northeast coast of Iceland another head wind was encountered, which lasted 7 days.

"On August 21, the day of the eclipse, we had our first clear weather for 2 weeks and had a fine view of the eclipse, getting numerous photographs and noting times of contact. From there to Reykjavik, where we arrived on August 24, the trip was without incident, with the exception of 2 days' head winds, just before entering the harbor."

The *Carnegie* thus reached a high northerly latitude and secured a valuable series of magnetic observations in a region of high magnetic latitude. The largest observed dip was 81°.3, the value of the horizontal intensity at this point being 0.081 C. G. S. unit.

As evidence of the promptness with which the results of the magnetic observations, obtained on board the *Carnegie*, may be made known, the following facts are cited: The values of the magnetic declination (the variation of the compass, as the mariner calls it) obtained on the portion of the cruise from Long Island Sound to Hammerfest, June 10 to July 2, 1914, were printed in the Journal of Terrestrial Magnetism which was issued on September 1, 1914; the values observed from Hammerfest to Reykjavik, July 26 to August 23, 1914, were received at Washington on September 21, and those from Reykjavik to Greenport, September 15 to October 11, were received on October 16; the results of the entire cruise appear in this report (table 1). The values of the other magnetic elements (dip and intensity) were received at Washington at the same time as the declination values. They are not published here, as the mariner does not need these particular elements for his immediate purpose, and, furthermore, the values require certain corrections which can not well be determined until a discussion has been made of all the shore observations and comparisons secured during the cruise.

Table 1 shows that, in general, the chart correction has a minus sign for nearly the entire cruise from Long Island Sound to Hammerfest, and thence to Reykjavik. This means that the chart values of west compass direction are, in general, too low on the values observed aboard the *Carnegie*. The general result found on the present cruise of 1914 is thus in entire agreement with that announced for the first cruise of the *Carnegie*, New York to Falmouth, England, in 1909.

TABLE 1.—*Magnetic declinations and chart corrections observed on the Carnegie from Long Island Sound to Hammerfest, Norway, and to Reykjavik, Iceland, and thence to Brooklyn, New York, June to October, 1914.*[1]

Date.	Position.		Carnegie.	Chart values.			Chart corrections.		
	Lat.	Long.		Brit.	Ger.	U. S.	Brit.	Ger.	U. S.
1914.	° ′	° ′	°	°	°	°	°	°	°
June 10	40 44 N.	70 05 W.	−12.9	−13.1	−13.1	−12.0	+0.2	+0.2	−0.9
11	40 35 N.	68 33 W.	−14.6	−14.2	−14.2	−13.6	−0.4	−0.4	−1.0
11	40 32 N.	67 09 W.	−15.4	−15.2	−15.1	−14.6	−0.2	−0.3	−0.8
12	40 26 N.	65 39 W.	−16.6	−16.0	−15.9	−15 5	−0.6	−0.7	−1.1
12	40 14 N.	63 24 W.	−17.7	−17.1	−17.3	−16.4	−0.6	−0 4	−1.3
13	40 03 N.	60 41 W.	−19.0	−18.6	−18.6	−17.7	−0.4	−0.4	−1.3
14	40 09 N.	55 41 W.	−22.1	−21.4	−21.6	−19.9	−0.7	−0.5	−2.2
15	39 22 N.	51 51 W.	−22.7	−22 3	−22.6	−20.7	−0.4	−0.1	−2.0
15	39 20 N	51 48 W.	−22.8	−22.3	−22.5	−20.7	−0.5	−0.3	−2.1
16	40 07 N.	50 26 W.	−23.5	−23.3	−23.6	−21.8	−0.2	+0.1	−1.7
16	41 23 N.	48 32 W.	−25.5	−24.6	−24.7	−23.4	−0.9	−0.8	−2.1
18	44 39 N.	44 18 W.	−28.2	−28.1	−27.5	−27.4	−0.1	−0.7	−0.8
18	45 43 N.	41 35 W.	−28.8	−28.8	−28.3	−28.3	0.0	−0.5	−0.5
19	46 10 N.	37 43 W.	−28.8	−28.8	−28.2	−27.8	0.0	−0.6	−1.0
20	46 20 N.	36 29 W.	−29.1	−28.6	−28.1	−27.7	−0.5	−1.0	−1.4
21	49 00 N.	30 32 W.	−27.8	−28.4	−28.2	−28.4	+0.6	+0.4	+0.6
22	50 19 N.	28 54 W.	−28.2	−28.3	−28.3	−28.7	+0.1	+0.1	+0.5
23	52 32 N.	25 36 W.	−28.1	−27.8	−27.5	−28.5	−0.3	−0.6	+0.4
24	55 24 N.	20 51 W.	−27.0	−26.7	−27.3	−27.2	−0.3	+0.3	+0.2
24	55 28 N.	20 46 W.	−27.6	−26.7	−27.3	−27.2	−0.9	−0.3	−0.4
24	55 38 N.	20 32 W.	−26.9	−26.7	−27.2	−27.1	−0.2	+0.3	+0.2
25	56 48 N.	18 28 W.	−27.4	−26.1	−26.8	−26.6	−1.3	−0.6	−0.8
25	57 48 N.	16 41 W.	−26.4	−25.4	−26.3	−25.9	−1.0	−0.1	−0.5
25	58 00 N.	16 20 W.	−26.4	−25.3	−26.2	−25.8	−1.1	−0.2	−0.6
26	60 22 N.	11 58 W.	−24.4	−23.8	−24.6	−24.4	−0.6	+0.2	0.0
27	61 36 N.	9 12 W.	−23.4	−23.1	−23.4	−23.1	−0.3	0.0	−0.3
27	62 46 N.	6 08 W.	−22.1	−21.9	−21.6	−21.7	−0.2	−0.5	−0.4
28	64 03 N.	1 31 W.	−19.5	−19.5	−19.0	−19.0	0.0	−0.5	−0.5
30	67 33 N.	7 40 E.	−13.0	−12.9	−13.0	−13.4	−0.1	0.0	+0.4
July 2	70 36 N.	21 19 E.	− 2.7	− 3.5	− 2.5	− 3.6	+0.8	−0.2	+0.9
28	73 28 N.	16 04 E.	− 7.1	− 6.9	− 6.7	....	−0.2	−0.4	....
28	73 44 N.	16 01 E.	− 7.2	− 7.1	− 6.9	....	−0.1	−0.3	....
30	74 28 N.	16 44 E.	− 6.6	− 6.6	− 6.3	....	0.0	−0.3	....
31	75 07 N.	16 15 E.	− 7.7	− 7.0	− 6.7	....	−0.7	−1.0	....
Aug. 1	76 10 N.	15 14 E.	− 8.6	− 7.5	− 7.7	....	−1.1	−0.9	....
1	77 17 N.	12 13 E.	−11.9	− 9.1	−10.3	....	−2.8	−1.6	....
2	78 06 N.	9 11 E.	−14.4	−12.2	−13.0	....	−2.2	−1.4	....
4	79 28 N.	10 22 E.	−14.3	−11.2	−12.1	....	−3.1	−2.2	....
4	79 13 N.	10 28 E.	−14.4	−11.3	−12.1	....	−3.1	−2.3	....
5	78 50 N.	8 49 E.	−16.2	−12.4	−13.3	....	−3.8	−2.9	....
8	76 53 N.	4 00 E.	−18.5	−15.9	−17.0	....	−2.6	−1.5	....
12	69 33 N.	6 26 W.	−24.7	−23.1	−24.1	−24.0	−1.6	−0.6	−0.7
12	68 38 N.	7 03 W.	−23.9	−23.4	−24.0	−24.1	−0.5	+0.1	+0.2
13	67 25 N.	7 12 W.	−24.6	−23.4	−23.8	−23.1	−1.2	−0.8	−1.5
13	66 29 N.	5 43 W.	−23.5	−22.3	−22.4	−22.5	−1.2	−1.1	−1.0
16	66 21 N.	7 23 W.	−23.3	−23.3	−23.6	−23.5	0.0	+0.3	+0.2
17	65 22 N.	8 13 W.	−24.3	−23.6	−23.8	−23.8	−0.7	−0.5	−0.5
18	65 13 N.	8 45 W.	−24.4	−23.8	−24.1	−24.2	−0.6	−0.3	−0 2

[1]Minus sign indicates west declination, and plus, east declination. The chart-values were those scaled from the following isogonic charts: British Admiralty No. 2598 for 1912; Reichs Marine Amt. No. 383 (Tit. XIV, No. 1) for 1915, and beyond its limits, Tit. XIV, No. 2, for 1910; U. S. Hydrographic Office No. 2409 for 1910. The scaled values were corrected for secular change according to the data given on the charts themselves.

TABLE 1.—*Magnetic declinations and chart corrections observed on the Carnegie from Long Island Sound to Hammerfest, Norway, and to Reykjavik, Iceland, and thence to Brooklyn, New York, June to October, 1914*—Continued.

Date.	Position.		Carnegie.	Chart values.			Chart corrections.		
	Lat.	Long.		Brit.	Ger.	U. S.	Brit.	Ger.	U. S.
1914.	° ′	° ′	°	°	°	°	°	°	°
Aug. 18	64 34 N.	8 43 W.	−24.5	−23.7	−23.7	−24.0	−0.8	−0.8	−0.5
20	63 56 N.	11 26 W.	−27.1	−25.0	−25.5	−25.4	−2.1	−1.6	−1.7
21	63 30 N.	13 54 W.	−27.6	−26.4	−26.3	−26.5	−1.2	−1.3	−1 1
21	63 25 N.	14 28 W.	−27.5	−26.7	−27 4	−27.0	−0.8	−0.1	−0.5
21	63 17 N.	15 23 W.	−28.9	−27.2	−27.9	−27.4	−1.7	−1.0	−1.5
23	63 39 N.	22 56 W.	−33.4	−33.2	−33.6	−33.6	−0.2	0.0	+0.2
23	63 55 N.	23 06 W.	−35.1	−33.6	−34.0	−34.0	−1.5	−1.1	−1.1
23	64 01 N.	22 54 W.	−33.9	−33.6	−34.0	−33.9	−0.3	+0.1	0.0
Sept. 15	61 00 N.	30 10 W.	−36.7	−37.0	−36.6	−37.7	+0.3	−0.1	+1.0
15	60 09 N.	32 04 W.	−37.2	−37.6	−37.4	−38.6	+0.4	+0.2	+1.4
16	58 45 N.	35 43 W.	−38.2	−38.6	−38.5	−39.8	+0.4	+0.3	+1.6
16	58 18 N.	37 51 W.	−38.1	−39.3	−39.3	−40.4	+1.2	+1.2	+2.3
17	58 12 N.	40 12 W.	−38.7	−40.2	−40.3	−41.2	+1.5	+1.6	+2.5
17	58 10 N.	41 16 W.	−39.3	−40.7	−40.8	−41.5	+1.4	+1.5	+2.2
18	58 08 N.	43 38 W.	−39.6	−41.4	−41.8	−42.2	+1.8	+2.2	+2.6
19	58 17 N.	50 25 W.	−43.0	−43.0	−44.0	−43.9	0.0	+1.0	+0.9
20	58 42 N.	52 53 W.	−44.8	−43.7	−44.9	−44.6	−1.1	+0.1	−0.2
22	54 44 N.	52 35 W.	−40.3	−37.5	−39.4	−39.5	−2.8	−0.9	−0.8
22	54 29 N.	52 22 W.	−39.4	−37.2	−38.9	−39.2	−2.2	−0.5	−0.2
23	53 40 N.	50 43 W.	−36.9	−36.5	−37.6	−38.5	−0.4	+0.7	+1.6
25	51 34 N.	49 03 W.	−34.3	−33.2	−34.6	−35.1	−1.1	+0.3	+0.8
27	49 43 N.	48 02 W.	−32.6	−32.5	−32.7	−32.5	−0.1	+0.1	−0.1
28	49 20 N.	47 25 W.	−32.3	−32.1	−32.3	−32.1	−0.2	0.0	−0.2
28	48 41 N.	47 23 W.	−31.5	−31 6	−31.6	−31.5	+0.1	+0.1	0.0
29	47 25 N.	48 18 W.	−30.3	−29.9	−30.0	−29.9	−0.4	−0.3	−0.4
29	46 42 N.	49 32 W.	−29.3	−29.0	−29.0	−28.8	−0.3	−0.3	−0.5
30	46 54 N.	50 43 W.	−29.6	−29.0	−29.0	−28.9	−0.6	−0.6	−0.7
30	46 59 N.	50 52 W.	−29.4	−29.2	−29.1	−29.0	−0.2	−0.3	−0.4
Oct. 1	46 33 N.	50 46 W.	−29.0	−28.6	−28.6	−28.5	−0.4	−0.4	−0.5
1	46 01 N.	50 54 W.	−28.7	−28.1	−28.0	−27.9	−0.6	−0.7	−0.8
2	45 14 N.	52 24 W.	−27.5	−26.9	−26.7	−26.3	−0.6	−0.8	−1.2
2	44 56 N.	53 22 W.	−27.2	−26.3	−26.4	−25.7	−0.9	−0.8	−1.5
3	44 01 N.	56 16 W.	−25.0	−24.5	−24.6	−24.0	−0.5	−0.4	−1.0
3	43 27 N.	57 16 W.	−24.0	−23.7	−23.7	−22.9	−0.3	−0.3	−1.1
4	43 28 N.	57 40 W.	−23.8	−23.5	−23.6	−22.6	−0.3	−0.2	−1.2
4	43 02 N.	58 55 W.	−23.0	−22.5	−22.5	−21.5	−0.5	−0.5	−1.5
5	42 50 N.	59 57 W.	−22.5	−21.8	−21.8	−20.7	−0.7	−0.7	−1.8
5	42 57 N.	60 35 W.	−21.8	−21.7	−21.5	−20.5	−0.1	−0.3	−1.3
6	42 22 N.	63 31 W.	−20.1	−19.4	−19.1	−18.8	−0.7	−1.0	−1.3
6	42 18 N.	63 47 W.	−18.8	−19.1	−18.8	−18.5	+0.3	0.0	−0.3
7	41 45 N.	65 39 W.	−17.2	−17.3	−16.9	−16.6	+0.1	−0.3	−0.6
7	41 34 N.	66 22 W.	−16.8	−16.6	−16.4	−16.1	−0.2	−0.4	−0.7
8	41 37 N.	66 45 W.	−16.2	−16.4	−16.2	−15.8	+0.2	0.0	−0.4
8	41 20 N.	66 37 W.	−16.5	−16.2	−16.1	−15.7	−0.3	−0.4	−0.8
9	40 58 N.	68 10 W.	−15.0	−14.9	−14.8	−14.3	−0.1	−0.2	−0.7
10	40 52 N.	69 08 W.	−14.3	−14.1	−14.1	−13.3	−0.2	−0.2	−1.0
10	40 52 N.	70 06 W.	−13.1	−13.2	−13.2	−12.1	+0.1	+0.1	−1.0
11	41 09 N.	72 01 W.	−11.2	−12.0	−11.6	−11.0	+0.8	+0.4	−0.2

Particular pains were taken to secure control observations at the point of intersection of the tracks of 1909 and 1914; thus it was found that west magnetic declination, in latitude 50° 30′ north and longitude 28° 36′ west, is decreasing, *i. e.*, the north end of the compass is swinging to the east, at an average annual rate of about 6′, or 0°.1. Furthermore in latitude 48° 22′ north and longitude 48° 08′ west, it was found that, between 1909 and 1914, the north end of the compass swung to the east at the average annual rate of 4′.6.

On account oflocal disturbances in the general neighborhood of Reykjavik, it was not deemed worth while to attempt swings. It was decided instead to make such observations at sea after leaving Reykjavik. Various shore stations were occupied, as also Dr. Angenheister's station of 1910. The necessary shore observations and standardizations of the ocean instruments having been completed, the *Carnegie* sailed from Reykjavik on September 15, bound for Greenport, Long Island. She arrived at the latter port on October 12; after the completion of the shore and harbor observations, both in terrestrial magnetism and atmospheric electricity, she proceeded to Brooklyn and was berthed at Beard's Yacht Basin on October 21.

Besides the magnetic work, the observations in atmospheric electricity were continued on the present cruise. It has already been mentioned that improved methods and instruments for this work have been introduced as the result of Dr. Swann's theoretical and experimental researches in the Department laboratory at Washington.

The following extracts from the record of meteorological observations made between Hammerfest and Reykjavik will be of interest:

"In most cases the fogs were not of very long duration and were accompanied by mist and light showers in between. Off the coast of Spitzbergen quite a considerable wind accompanied the fog.

"At 5 p. m., August 19, 1914, latitude 64° north, longitude 9°.4 west, land was sighted, bearing 331° magnetic. It appeared as a rocky island sharply defined. Later it gradually flattened out and disappeared. Land in that direction was 180 miles distant.

"August 26, 1914. We have noted the aurora at Reykjavik, Iceland, several times. The long white band went nearly across the sky. At first it was a single path, and later seemed to shade off in three distinct portions parallel to one another. The general trend of the path was from southwest to northeast, true. At $11^h\ 30^m$ p. m., local time, there were two bands, the end of which ended in a 'whorl.'"

1. View of Magnetic Station, Derna, Libia, Africa.

2. Testing Magnetic Observatory of the Department of Terrestrial Magnetism, at Washington.

LAND WORK.

AFRICA.

At the beginning of the year, Observer D. W. Berky was completing his expedition along the Niger River from Timbuktoo. After occupying a station at Lagos, Nigeria, he returned to Washington on January 12.

Observer H. E. Sawyer, who had assisted Mr. Berky in the trans-Saharan expedition, was observing in French West Africa at the beginning of the year. Having observed at Bathurst, Gambia, he returned to Dakar, Senegal, and thence traveled along the coast of Liberia, French West Africa, Togoland, and Nigeria. Up to the time of his arrival at Lagos, March 14, he had occupied 6 stations in Liberia, 5 stations in French West Africa, and 3 stations in Togoland. From Lagos he took up a general magnetic survey of Nigeria, going as far north as Kano, and thence west-southwest to Yola, on the River Benue, where he arrived June 29. From this point he made a trip into northern Cameroon and occupied a station at Garua. Early in July he left Yola for Lokoja, Nigeria, via the River Benue, arriving there on August 17. From Lokoja he proceeded up the Niger to Baro, thence returning to the coast. By the end of the year the general magnetic survey of Nigeria will have been completed, as far as present conditions permit.

Observer D. M. Wise left New York City on January 31 to take up work in the Belgian Congo. En route he occupied 2 stations in the Madeira and Canary Islands. He also secured observations at Konakry, French West Africa. Arriving at Boma on March 9, he proceeded via steamer and railway to Leopoldville, where he made his final preparations for the trip into the interior. He left Kinshasa (near Leopoldville) on March 31 and arrived at Stanleyville on May 11, and at Lowa during the latter part of June. From Lowa he proceeded by rail and steamer to Bukama, and thence by caravan to Kambove. While on this part of the journey he made a side trip to the east from Kabalo, latitude about 6° south, along the line of the proposed railway, to within 35 kilometers of Lake Tanganyika. From Kambove he proceeded southward to Elisabethville, where he arrived during the latter part of July. From Elisabethville Mr. Wise continued the trip by caravan to a navigable point on the Kasai River, and thence by boat to Kinshasa. Conditions permitting, he will proceed thence to Brazzaville and Loango, on the French Congo Coast. During Mr. Wise's work, he succeeded in occupying a number of stations where magnetic observations had been secured previously by various Belgian expeditions. With the aid of the data now obtained, it may be found possible to construct general magnetic charts of the Belgian Congo of sufficient accuracy for our purpose.

Observer W. F. Wallis having completed his work in Italy, arrived in Tripoli on December 15. After reoccupying our station here, as estab-

lished for the Department by Professor Luigi Palazzo, he made various inquiries and preparations for a trans-Saharan expedition from Tripoli to Lake Chad. At the end of December he left Tripoli for an expedition along the northern coast of Tripolitana, during which he observed at eight stations, his most eastern station being Tobruk. Thence he proceeded to Alexandria, and, after securing observations there, he obtained intercomparisons between his instruments and those of the Helwan Observatory. On the return to Alexandria, he carried out a caravan trip to Sellum, Egypt, observing at 8 stations. Leaving Alexandria on May 16, he reoccupied our previous stations at Suez and Aden, Arabia. From Aden the journey was continued to the French Somali coast, observations being made at Jibuti and thence at 8 stations en route to Adis Abeba, Abyssinia, where he arrived on July 8. From Adis Abeba he carried out a caravan trip northward to Massaua, on the Red Sea, where he arrived early in October. He then returned to Tripoli.

ASIA.

The magnetic work in Asia during the year had to be confined to that of Dr. C. K. Edmunds. During April and May he constructed on the campus of the Canton Christian College, at Honglok, near Canton, two non-magnetic huts to serve for comparisons and standardizations of magnetic outfits. During July and August he made two short excursions from Canton, securing observations at about 8 stations, one of which was the secular-variation station at Macao, China. It was not found possible to undertake more extensive work in China during this year. Dr. Edmunds was accompanied on his trips by a Chinese assistant, Mr. H. Suen.

AUSTRALASIA.

The general magnetic survey of Australasia, under the charge of Observer E. Kidson, has been practically completed during the present year. During November 1913, Mr. Kidson was still at work in Queensland, observing at points along the east coast as far north as Townsville and on the railway line between the coast and the western part of the state. He returned to Brisbane the latter part of November. His assistant, Observer F. Brown, after the conclusion of a successful trip by automobile, was at work in Northern Queensland, especially in Cape York Peninsula, beginning at the secular-variation station on Thursday Island and ending at the secular-variation station, Cooktown. Thence he proceeded to Hobart, Tasmania, arriving there January 6.

From the end of December to January 21, Mr. Kidson continued the magnetic-survey work in Tasmania and King Island, where he occupied 10 stations, including a number of stations that had been previously occupied in the course of the Tasmanian Magnetic Survey. He arrived at Melbourne on January 23. After a month's leave of absence he

resumed the work in South Australia. Upon Mr. Brown's arrival at Hobart, an intercomparison of instruments, used by Messrs. Kidson and Brown, was secured; thereafter Mr. Brown occupied 3 stations in Tasmania and Flinders Island.

Early in March Messrs. Kidson and Brown compared dip instruments at the Melbourne Observatory; proceeding thence to Blackwood, South Australia, an intercomparison of the instrumental outfits to be used by Messrs. Kidson, Parkinson, and Brown was made. During the last half of March Mr. Kidson observed at 4 stations in the southeastern part of South Australia with Observers W. C. Parkinson and A. L. Kennedy and instructed them in the field operations and methods of the Department. Having planned the field-work of the 3 observers of his party (Messrs. Brown, Kennedy, and Parkinson), Mr. Kidson proceeded during the first part of May to Perth, and thence to Coolgardie, Western Australia, where repeat observations were made. At this point he outfitted for his caravan trip to Wiluna, and thence along the Canning stock route to Hall's Creek and Wyndham. He observed at Wiluna on June 3, having secured 5 stations en route from Coolgardie. He arrived at Hall's Creek on August 21, having secured 33 stations on the trip across the desert. After reaching Wyndham on September 22, Mr. Kidson proceeded along the coast to Perth, where he arrived on October 3. At Perth his entire party was assembled; here the computations of the field observations were made and the various instrumental equipments were intercompared.

Observer A. L. Kennedy, previously a member of the Australasian Antarctic Expedition, was appointed for the balance of the year, on March 16, at Adelaide, and assigned at once to Mr. Kidson's party. After the trip of instruction with Mr. Kidson, referred to above, Mr. Kennedy first undertook a caravan trip in the northeastern part of South Australia and the southwestern part of Queensland. He went by rail from Adelaide to Farina, and thence by caravan around the southeast end of Lake Blanch to a point near the east boundary of South Australia, about latitude 28°. From this point he proceeded north through Haddon Station into Queensland, and west to Birdsville, Queensland, thence in a generally southerly direction, through South Australia, to Hergott Springs on the railway, returning to Adelaide about August 1. Preparations were then made for the caravan trip from Port Augusta, at the head of Spencer Gulf, northwesterly to the north of Lake Gairdner, and thence directly west across the Victoria Desert to Eucla, Western Australia. During both of these caravan trips Mr. Kennedy secured observations at stations spaced 30 to 50 miles apart.

Observer W. C. Parkinson left Washington on February 2, via San Francisco and Honolulu, to report to Mr. Kidson for duty in Western Australia. He arrived at Adelaide on March 4. After the preliminary

work in South Australia, he proceeded with Mr. Kidson to Perth. During the latter part of April and the month of June, Mr. Parkinson was engaged on field-work in the western part of Western Australia. Starting at Bunbury, he proceeded overland in an automobile, purchased for the use of the expedition, to Albany. From Albany the party traveled generally eastward, with various side trips, and arrived at Eucla, in the extreme southeast corner of Western Australia, on June 10. On the return trip westward it was necessary, on account of the breakdown of the automobile, to proceed to Kalgoorlie, and thence to Perth by rail. Magnetic observations at 14 stations, 4 of which were repeat stations, had been secured. Mr. Parkinson was accompanied on this expedition by Mr. W. B. Alexander, of the Western Australian Museum, who made a collection of natural-history specimens in this little-visited portion of the Commonwealth. During the month of July Mr. Parkinson was engaged at Perth in the reduction of his observations and preparations for the next trip. At the end of July he left by automobile, by way of the rabbit fence, to Sandstone, and thence by the stock route through Marble Bar to Port Hedland. After completing this trip Mr. Parkinson returned to Perth in October.

Mr. F. Brown secured observations with Mr. Parkinson at Adelaide early in March and, after the comparisons of his instruments with Mr. Kidson's, proceeded to Brisbane and Rockhampton, repeat observations being made at each of these points. He next took up work in the Northern Territory, establishing a line of stations from Queens Channel, along the Victoria River inland to Katherine River, and thence along the route previously followed by Mr. Kidson in 1912 to Port Darwin. From Port Darwin trips were made to Melville and Bathurst Islands and three stations were occupied. Mr. Brown returned to Darwin about the middle of May and made repeat observations at Mr. Kidson's station. During June he secured observations on the Roper and McArthur Rivers, on the west coast of the Gulf of Carpentaria, and at Sir Edward Pellew's Group. During July observations were made along the coast of Van Diemen Gulf, and later a trip to the Wessel Islands was made. The work planned for in the Northern Territory was practically completed during September. Mr. Brown then returned in October to Perth and reported to his chief of party.

Throughout the work the members of Mr. Kidson's party have had the cordial cooperation of the various governments. The work accomplished during the present fiscal year has been of an unusual nature, and difficult conditions of travel were successfully overcome.

EUROPE.

The only work in Europe during the fiscal year has been by Observer W. F. Wallis, who, while en route to Africa, occupied four secular-variation stations in Italy. He obtained an intercomparison of his outfit with that of Professor Palazzo at Terracina, near Rome.

NORTH AMERICA.

Chief Observer Peters, assisted by Observer Berky, carried out an expedition to Hudson Bay, on board the gasoline schooner *George B. Cluett*, chartered from the International Grenfell Association, of St. John's, Newfoundland. The magnetic observations were made both on land and on board. The vessel is not a non-magnetic one like the *Carnegie*. The instrumental equipment included, besides the land instruments, a liquid compass and deflector for declinations and intensities, and a marine dip circle. Messrs. Peters and Berky arrived at Battle Harbor, Labrador, on June 28. Although the *Cluett* was available for their work on July 8, it was not possible, on account of unusually bad ice conditions, to leave Battle Harbor before July 31. For the determination of ship deviations the vessel was "swung" prior to departure. The *Cluett* arrived at Hopedale, Labrador, on August 8, by the inland passage. Unusual ice conditions delayed entering Hudson Bay until September 2; the vessel was obliged to leave Hudson Strait again on September 28, and returned safely to Battle Harbor, Labrador, on October 3. In addition to observations at various land stations en route from Battle Harbor to Hudson Bay, valuable results were obtained aboard, the vessel being swung each time, in order to eliminate the disturbing element of the vessel. The Department is under obligations to the United States Coast and Geodetic Survey for the loan to this expedition of Dover dip circle No. 4655.

SOUTH AMERICA.

Observer H. F. Johnston was at work in South America at the beginning of the fiscal year and continued in the field during November to January. He returned to Washington on February 3. His observations were made in Uruguay, Paraguay, and Brazil, the last station being Corumbá, Brazil.

Observer A. D. Power was en route at the beginning of the fiscal year from Brazil to British Guiana, on the headwaters of the Rio Branco. He arrived at Georgetown, British Guiana, early in December, having observed at nine stations, and returned to Washington on December 18. At several of Mr. Power's stations observations had been made previously by the Department; thus valuable secular-variation data were secured.

Mr. Power left Washington again on March 9 for Caracas, Venezuela, where he arrived March 20. After reoccupying our station there, he proceeded overland to San Fernando, on the Apure River. Thence the trip was continued up the Meta River, observations being made en route, and Mr. Power arriving at Bogotá, Colombia, June 2. During this trip 20 stations were established in Venezuela and Colombia. From Bogotá he proceeded south to Neiva, Colombia, where he arrived July 8. After reoccupying our station at this point, he resumed the

journey, via the Caqueta and Putamayo Rivers, through the southeastern part of Colombia, into Brazil, and thence on the Amazon River to Manaos, arriving there on September 24. With the completion of Mr. Power's expedition, the general magnetic survey of South America north of the Amazon is almost concluded. Mr. Power returned to Washington on October 17.

Observer H. R. Schmitt left Washington on March 6 for magnetic-survey work in Peru, Bolivia, Chile, and Brazil. En route to Lima he reoccupied our station at Kingston, Jamaica. Having occupied the repeat stations at Lima, Callao, and Mollendo, Peru, he entered Chile at Arica, and proceeded thence by rail to La Paz, Bolivia. From La Paz he successfully carried out a difficult overland expedition via Cochabamba to Corumbá, Brazil, where he arrived the latter part of June, having made magnetic observations, en route from Arica, at 20 stations. Early in July Mr. Schmitt left Corumbá bound for San Luiz, and thence down the River Guapore to Guayara-merim, where he arrived the middle of September. After securing observations at some of the stations occupied in this neighborhood by Observer Stewart in 1911, Mr. Schmitt proceeded by the Madeira River to Manaos, Brazil, arriving there the middle of October. Throughout the trip from Corumbá to Manaos, observations were made at an average distance apart of about 35 miles.

With the successful accomplishment of the two expeditions, Mr. Power's and Mr. Schmitt's, the general magnetic survey of the western countries of South America is rapidly nearing completion.

MISCELLANEOUS.

In addition to the above land work, the observers of the *Carnegie* established 5 stations in the vicinity of Hammerfest, Norway, as also a number of stations around the harbor of Reykjavik, Iceland; at the latter place marked local disturbances were found. Observations were also made by the *Carnegie* observers at Greenport and vicinity, in December 1913 and October 1914.

Throughout the year all of the observers have made, whenever possible, declination observations at close intervals, and for as many hours as possible, on the first and fifteenth days of each month. On August 21, during the total solar eclipse, a special program of work was carried out by many of the observers, at whatever station they happened to be at the time, as also by Mr. Fleming at Washington. Special observations were likewise made on board the *Carnegie* on this day, she being at sea off the southeast coast of Iceland. Data have also been received from a number of magnetic observatories which participated in the program of international magnetic and allied observations during this eclipse, as proposed by the Department.

DETAILS OF WORK IN WASHINGTON.

INVESTIGATIONAL AND PUBLICATION WORK.

On pages 301–303 a general account is given of the various researches under this head. A fuller statement respecting the chief investigations is contained in the following abstracts:

On the study of methods of seeking hidden periodicities, with some applications to magnetic and Sun-spot data.[1] G. N. Armstrong and C. R. Duvall.

The main part of the work was devoted to recurring-series methods, which were first investigated by Lagrange in 1772. In his dissertation[2] the first of the authors developed these methods, with numerous applications (1) to computed values of an assumed periodic function for the purpose of testing the powers and limitations of the methods; and (2) to observational data of suspected periodicity.

Assuming that any periodicity in a series of numbers may be expressed as a sum of sine terms, the number of different periods being equal to the number of sine terms in the sum, it is shown in the recurring-series method that the necessary condition for the existence of periodicity in the given numbers is the vanishing of certain functions of these numbers. It was found that the most convenient form for applying the vanishing conditions is that of determinants made up of the given numbers in the manner explained in the "reciprocal scale" method of the dissertation.[2] If all such determinants of the $(n+1)^{th}$ order vanish, the condition is satisfied for the existence of n different periods in the given numbers. The solution of certain linear equations, greater than n in number, gives the n "scale coefficients." The method of least squares may be applied in this solution. An equation of the n^{th} degree in one unknown is then formed, the coefficients being certain simple functions of the "scale coefficients." To each real root of this equation, which is not greater than 2 in absolute value, there corresponds an independent period of the given numbers, the cosine of the period angle being equal to one-half of the root in question. Other values of the roots correspond to exponential and hyperbolic functions.

The great difficulty in the application of the method is encountered when the vanishing of the determinants is tested. Even for computed values of a function of known periods, the failure to vanish may be surprisingly large. Here the only errors in the given numbers are due to the "rounding off" process, and the failure to vanish is entirely due to accumulations from these errors. In the application to observational material the trouble with the vanishing of the determinants is likely to be very much greater. Not only are the given observations uncertain, often by unknown amounts, but there is generally also a question of the validity of the assumption that a periodic function of a specified form may be made to represent these observations. It is extremely desirable, therefore, to have some criterion by which to judge of the exactness with which the determinants should vanish.

About the time the present work was undertaken, an article came to hand in the May (1914) number of the Monthly Notices of the Royal Astronomical Society, by Professor J. B. Dale, in which just such a criterion was proposed.

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[1]Abstract of work done during July and August 1914, at the Department of Terrestrial Magnetism. Fuller publication is to be made in the journal Terrestrial Magnetism and Atmospheric Electricity.

[2]Armstrong, G. N. Eine Untersuchung der Anwendbarkeit rekurrenter Reihen zur Aufsuchung versteckter Periodizitäten. München, Dissertation, K. Technische Hochschule. 1913 (pp. 96 with figs.). 24 cm.

This criterion has been found very useful, though the very first test of it on a computed function showed that it was not infallible. During the progress of the work a second criterion has been devised, which, though it is free from some of the objections to Dale's, is still far from final.

In the dissertation referred to, the annual mean of the diurnal range of the magnetic declination for three stations, Christiania, Milan, and Prague, was discussed. The means were taken of the values at these three stations for the years 1841 to 1910. "Five-year" means were then taken of these "three-station" means, these values corresponding to the middle years of the 5-year groups in question. A value is thus obtained for each year from 1843 to 1908. The mean of these 66 values was finally subtracted from each individual value, giving the series of 66 numbers shown in column 9, page 94, of the dissertation. The general result from the application of the method to these magnetic data is that a period of about 11.4 years comes out, no matter how the observations are treated. Another period of about 22 years and a third in the neighborhood of 70 years are almost as persistent. Similar periods were obtained from an application of the method to the Wolf-Wolfer system of relative sun-spot numbers covering the same period as the magnetic data. The investigation is being continued.

Regarding improvement of appliances for measurement of the Earth's magnetic elements by magnetic and electric methods. (Progress report). L. A. Bauer. Terr. Mag., vol. 19, pp. 1–18 (1914).

The instruments for magnetic measurements, employing distinctively magnetic methods, have now reached the requisite stage of perfection for meeting the practical requirements, both on land and at sea. However, the desire is to devise and try out new methods—for example, those based on electrodynamic or electric principles, with a two-fold object in view: (1) to obtain more expeditiously than is possible with the type of magnetometer now in general use, a magnetic measurement within the relative accuracy required for a successful study of the magnetic variations; (2) to obtain another control, by means of a distinctively different method, on the absolute accuracy of the present magnetic standards. The present report summarizes what has been done thus far with respect to improvement of the appliances and methods for the measurement of the terrestrial-magnetic elements and what is still further to be undertaken.

Magnetic methods.—The Department of Terrestrial Magnetism, in its various designs of magnetic instruments, has had to consider especially the demand and requirements of field-work, on land and at sea, in all parts of the Earth, and has been obliged to face and overcome difficulties not immediately apparent to an outsider or to one not himself actively engaged in magnetic work. Judging from the experiences since the observational work began, 9 years ago, the instruments have met satisfactorily all the varied requirements of difficult field-work. Furthermore, the numerous comparisons made with these same instruments from time to time at observatories in all parts of the Earth and between observers in the field have demonstrated that, with proper care, the constancy of the instrumental constants can be preserved, even during strenuous field campaigns, well within the practical requirements. Even with these field types of instruments it has been shown repeatedly that the adopted Department standard can be reproduced, in horizontal intensity, for example, to about 1 part in 10,000. The chief remaining difficulty is satisfactory dip observations. Accordingly, in the Department's latest instrument, an earth inductor has been combined with the magnetometer (*cf.* article by J. A. Fleming and J. A. Widmer, Terr. Mag., vol. 18, 1913, pp. 105–110). During the present year this instrument has been tested in the field with success.

As the result of numerous comparisons, it would seem safe to conclude that the H, or horizontal-intensity, standards of Kew, Potsdam, and Washington (Department of Terrestrial Magnetism) give an absolute accuracy within 1 part in 10,000, except for some possible error which may be inherent in the magnetometer method but not yet disclosed. *In brief, to reach an accuracy in the determination of the Earth's magnetic field intensity within 1 in 10,000 by magnetic methods requires great pains, but it can be done, if necessary, and with a comparatively simple type of magnetometer.*

For all field requirements, an absolute accuracy of 5 in 10,000 amply suffices, and this can readily be secured with a properly constructed instrument. For observatory purposes, where the prime purpose is the study of the magnetic variations, it is a question chiefly of relative accuracy of the magnetometer employed. Various comparisons between skilled observers would indicate that their instrumental difference as resulting from any one set of careful observations extending over about an hour and a quarter need not differ from the mean of several days' observations by much more than about 1 in 10,000. *If, then, further improvement is sought in magnetic measures, it should be in the direction of securing the desired degree of accuracy with less labor and less time.* The chief direction in which the present field magnetometers remain to be improved is the partial or total elimination of oscillations; the transport of such a delicate piece of mechanism as a chronometer, in comparatively unexplored regions, is a continual source of worry to the observer.

When the ocean work of the Department was begun in 1905, it was necessary either to design entirely new or to modify considerably existing devices. There have resulted thus the following *new instruments, for use at sea*, designed as well as chiefly constructed by the Department:

C. I. W. deflector for determining the magnetic declination (D) and the horizontal intensity (H), designed by L. A. Bauer and J. A. Fleming (see Terr. Mag., vol. 11, 1906, pp. 79–82; vol. 14, 1909, pp. 167–168; and vol. 18, 1913, pp. 57–62).

C. I. W. modified L. C. dip circle for determining the magnetic inclination and the total intensity, constructed by A. W. Dover, according to specifications of L. A. Bauer (see Terr. Mag., vol. 11, 1906, pp. 77–78, and vol. 14, 1909, pp. 164–166).

C. I. W. marine collimating compass, primarily for determining D, but may also, if desired, be adapted to measuring H, designed by W. J. Peters (see Terr. Mag., vol. 14, 1909, pp. 17–24).

C. I. W. marine earth inductor, designed by N. E. Dorsey and J. A. Fleming (see Terr. Mag., vol. 18, 1913, pp. 1–48).

With these instrumental devices, an accuracy in ocean magnetic work has been secured which, under favorable conditions and devoting the same time as in land work, do not fall much short of the general accuracy of land field-work.

Electric methods.—One great disadvantage of the earth inductor, in its present form, lies in the fact that it is not readily adapted to ex-meridian observations, such as would be requisite when working in the vicinity of a magnetic pole. Or, if an observer elsewhere accidentally makes a mis-setting, there is no such simple formula, as in the case of the dip circle, for computing the true dip from the ex-meridian one. Only under certain conditions can ex-meridian observations with the earth inductor be utilized, as was shown in the investigation "On the theory of the earth inductor as an inclinometer," made for the Department by Dr. N. E. Dorsey and published in Terrestrial Magnetism, vol. 18, 1913, pp. 1–38.

The requirements for measuring the intensity of the Earth's magnetic field by balancing it against that of a field produced by a current in some form of coil, common to the methods thus far proposed, are: (a) accurate knowledge of the current; (b) accurate knowledge of the essential dimensions of the coil,

and the choice of a coil of such a form that the field at its center and the variation of the field over small distances are capable of being accurately calculated. When the coil is properly chosen, it would appear that the field due to it can be determined to a degree of accuracy surpassing that usually required for the determination of H, or at any rate surpassing that obtained in the same time by the magnetic method of measuring the field. The constant of the coil should, in a properly constructed one, be capable of being known at least within two or three parts in 10^5, and, with the modern refinements, a corresponding accuracy in the current measurements seems readily possible. The accuracy of the current measurements, so far as the observer is concerned, depends on the accurate knowledge of a standard resistance, and of the e. m. f. of a standard cell. The proposed methods, by which the field due to the coil is compared with that of the Earth, fall into two classes: (1) methods involving the measurement of a deflection, the coil being used in fact as a galvanometer; (2) methods in which the field due to the coil is compared with the Earth's field by balancing it directly against that field, the comparison being made by some appropriate method.

In the first of these classes belongs Watson's method,[1] the principle employed being that of the sine galvanometer. In 1912 the problem of measurement of the Earth's magnetic field by electrical methods was assigned to Dr. N. E. Dorsey, while he was connected with the Department as Research Associate. As the result of his study and his extensive experience in electrical measurements in the United States Bureau of Standards, he likewise finally chose, as did Watson, the absolute sine galvanometer for measuring H, the horizontal intensity. Dorsey preferred, however, the simple coil instead of the Helmholtz arrangement and, of course, proposed measuring the current according to the most approved present-day methods. He made a thorough investigation of the theory of the instrument, examined into the various possible sources of error, and reached the conclusion that an absolute accuracy of 1 in 10,000 could be attained. Taking all things into consideration, a diameter of coil of about 25 cm. was chosen by Dorsey, and the number of turns and size of wire and other practical details of construction of the various parts of the entire apparatus were carefully considered by him and the necessary specifications and drawings were prepared. His investigation and designs were completed by March 11, 1913, but the proposed apparatus, pending completion of other studies and designs, has not yet been constructed.

To the second class belongs the method recently carried out by W. A. Jenkins, in Professor Hicks's laboratory at the University of Sheffield,[2] as also the method proposed by Schuster.[3] The methods thus far cited aim chiefly to determine the horizontal intensity, H, though they can readily be adapted, in general, also to measuring the magnetic declination, D.

Respecting the absolute accuracy attainable with electrical methods, it must be borne in mind that freedom from magnetic impurities in the material of the parts concerned is as essential as in the present magnetometers. In order to make the electrical method universally applicable, it may be found preferable to measure the total intensity rather than the horizontal or vertical component. If the same instrument were capable at the same time of measuring H, or the vertical component, Z, when suitable to do so, the inclination could likewise be obtained. Accordingly, designs for a universal instrument

[1]Watson, W.: A determination of the value of the Earth's magnetic field in international units. Phil. Trans. R. S., Ser. A, vol. 198, pp. 431–462 (London, 1902).
[2]Phil. Mag., vol. 26, pp. 752–774 (Oct. 1913).
[3]Terr. Mag., vol. 19, pp. 19–22 (1914).

with which all the magnetic elements may be measured by electrical methods are at present under consideration, but not yet definitely decided upon.

Summing up, it appears theoretically possible to construct an apparatus for measuring, by electrical means, the intensity of the Earth's magnetic field more expeditiously and, in general, with greater accuracy than with present magnetic methods, *provided* the necessary precautions be taken. Considerable experimentation appears yet to be required before it will be entirely advantageous to replace the present magnetic methods wholly by electrical ones.

The local magnetic constant and its variations. L. A. Bauer. Terr. Mag., vol. 19, pp. 113–125 (1914).

Good progress has been made by various investigators in establishing the relationship between fluctuations of the Earth's magnetism and those of the Sun's activity during the sun-spot cycle. The magnetic quantity most frequently used for this purpose has been the range of the diurnal variation—generally of the magnetic declination. In connection with a preliminary examination of this relationship, made in 1909, occasion was found to employ various other magnetic quantities. One of these was what is here termed the "local magnetic constant," which, under certain assumptions, is proportional to the magnetic moment of the Earth, or to the intensity of magnetization; it is thus a quantity which lends itself readily to physical interpretation.

The result of chief interest obtained from the 1909 investigation was that an increase in solar activity was accompanied, in general, during 1906 to 1909, by a decrease in the local magnetic constant. Since this investigation, Abbot's extensive observations, at Mount Wilson, California, and Bassour, Algiers, showing the fluctuations in the values of the solar constant of radiation for various years, have become available. The question arises whether any changes in the Earth's magnetism follow the same course as that of the solar constant.

In order to eliminate, as far as possible, the effects attributable perhaps to phenomena associated with sun-spots, the years chosen for the first tests were 1911 and 1912, the latter being the year of sun-spot minimum according to Wolfer's numbers. The magnetic data used for comparison with the Mount Wilson solar-constant values were those at the nearest magnetic observatory, namely, that of the United States Coast and Geodetic Survey at Tucson, Arizona, in longitude 29 minutes of time east of Mount Wilson. Accordingly, the local magnetic constant, $G=\sqrt{H^2+\frac{1}{4}Z^2}$, was obtained for each day on which there were solar-constant values of the grade good and above, H being the horizontal intensity and Z the vertical intensity. The time for which G applied was the same as for the solar-constant values. Next was tested the series of magnetic observations at Pola, on the Adriatic, the nearest observatory to Bassour, Algeria, via Pola, being in longitude 44 minutes of time east of Bassour.

As a provisional result, subject to modification when the final computations have been made, it was found that for the maximum change (10 per cent) observed in the solar-constant values, there is apparently a change in the local magnetic constant of about 0.03 per cent of its value, *i. e.*, about 10×10^{-5} C. G. S., decreased magnetic constant corresponding to increased solar constant. This result, if correct, is extremely interesting, not only because of its magnitude, but especially as it would be similar to that caused by heating a magnet, though it is not to be inferred at present that the effect is of this nature. The effect appears to be most pronounced for the observatories in the sun-lit portion of the globe, and seems to be reversed for the observatories

in the night portion, judging from the place where the corresponding solar observations are made. This is being looked into further.

It is seen that at the maximum a change in the magnetic constant, G, of about 10×10^{-5} C. G. S. might be associated with such changes in the solar radiation as are shown by Abbot's solar-constant values. However, during even a moderate magnetic storm G has changed 100×10^{-5}, and during a severe one, 1000×10^{-5}, or 1×10^{-2}, or by about $\frac{1}{30}$ (and even more) of its absolute amount. Magnetic storms can not, therefore, in general, be associated with changes in the solar radiation as measured by the solar constant. But there is a certain class of magnetic perturbations which, though sudden in appearance at any one station, do not occur simultaneously over the globe, but, instead, each time the disturbance occurred, only the observatories in the daylight zone recorded it. The change in the magnetic constant, G, for a typical disturbance of this class and on the average for the various observatories over the globe, is about 10×10^{-5} C. G. S., which is the amount that might be associated with a 10 per cent change in the solar radiation. If there are observable changes in the Earth's magnetism, associated with changes of solar radiation, then it is not surprising that magnetic observatories should continually be recording magnetic perturbations even on apparently undisturbed days, as, for example, the "elementary waves," or "magnetic pulsations," forever occurring during periods of absolute solar calms, as gaged by absence of sun-spots.

In the discussion of magnetic disturbances we may have to distinguish between two broad classes:

(1) The *curvilinear*, the more prominent as far as general magnitude is concerned, occurring practically over the whole Earth at the same time, seemingly initiated by streams of charged particles which are deflected from a straight path, when they come under the influence of the Earth's magnetic field, as to pass beyond and behind the sun-lit portion of the Earth.

(2) The *rectilinear*, occurring practically only over the portions of the Earth reached by the ordinary light radiations from the Sun.

The atmospheric-electric observations made on the second cruise of the *Carnegie*, 1909–1913. Report by C. W. Hewlett. Terr. Mag., vol. 19, pp. 127–170 (1914).

The atmospheric-electric observations, of which an account is given in this report, were made in pursuance of the plan of work assigned to the *Carnegie* by the Director of the Department of Terrestrial Magnetism. The observers received at all times the cordial support of Mr. W. J. Peters, while in command of the vessel. The final reduction and discussion of the observations have been made under the direction of Dr. W. F. G. Swann.

The atmospheric-electric work on board the *Carnegie* has been confined entirely to observations of the specific conductivity, the potential gradient, and the radioactivity of the atmosphere, the greater part of the observations consisting of the first two quantities named. The observations are divided naturally into three principal groups, according to the observer who made them. From New York to Colombo, E. Kidson conducted the observations; for the route from Colombo to Manila, owing to breakage in the instruments and the impossibility of having the requisite repairs made, there are no observations; from Manila to Tahiti, H. F. Johnston conducted the observations, and from Tahiti to New York, the work was carried on by C. W. Hewlett. For an account of the instruments and methods used, reference must be made to the original article.

The mean values of the total conductivity, the ratio of the positive to the negative conductivities, and the relative potential gradients are given in table 2. The conductivity is expressed in electro-static units.

It is to be remarked that only on one occasion during the whole cruise was a negative potential gradient observed, although observations were made frequently while it was raining. Usually during rain the potential gradient was very high, often exceeding the range which the electroscope would measure but it was always positive. On the one occasion when a negative potential gradient was observed the sky was nearly covered with clouds, but there was no rain. One very striking thing shown by the results is the large values for the conductivity and for q. The mean values of the conductivity found over land up to the present is not much greater than 2×10^{-4}, while q is less than 1.20. It is not probable that these large values of the conductivity can be due to large amounts of radioactive emanations in the atmosphere, for no clear relation between the radioactivity of the atmosphere and the conductivity was found. In view of the fact that, as shown in the paper, the errors in the measurements are such as to decrease the value found for the conductivity, it is deemed safe, *taking everything into consideration, to say that, over the oceanic regions where we observed, the average value of the conductivity is not less than* 3.25×10^{-4}, *q is not greater than 1.2, and that the mean value of potential gradient near the surface of the water is of the order of magnitude of 120 volts per meter.* During the passage from Falmouth to New York the observations of the radioactive content of the atmosphere formed a fairly complete set. The mean value for this cruise, of the activity, expressed in Elster and Geitel units, is 12.3, and the nature of the deposit on the wire was such that the activity decayed to half value in about 40 minutes.

TABLE 2.—*Mean resulting values.*

Observer.	$\lambda\times10^4$	No. of days involved.	$q=\frac{\lambda p}{\lambda n}$	No. of days involved.	Relative potential gradient.	No. of days involved.
Hewlett	3.25	202	1.22	202	122	186
Kidson	3.25	61	1.24	61	91	25
Johnston	2.43	70	1.27	70	127	54
Means	3.07	333	1.23	333	120	265

It has been attempted to discover any relations which may exist between the various atmospheric-electric elements or between these and the various meteorological factors. As a rule, the relations which have been found agree with those which have been previously known to exist on land. In most of the passages, both the potential gradient and q decrease with increase of the conductivity, and in the final mean this relation is shown very clearly. In the various portions of the passage from Tahiti to New York, large values of the conductivity correspond to small values of the relative humidity and vice versa. In the first half of the cruise, from New York to Tahiti, this relation is not clearly indicated in the separate portions, but it is revealed in the final means from New York to Colombo, and from Manila to Tahiti. There is also a clear relation between the conductivity and temperature, increase of temperature corresponding to the increase in conductivity. It is probable that the relation here is somewhat indirect, and is bound up with the effect of the temperature on the moisture conditions in the air. Increase of the conductivity is accompanied by little change in the *absolute* humidity. It was thought that possibly solar radiations might in some way affect the conductivity at the surface of the Earth, so that the observations of the cloudiness of the sky were grouped according to the conductivities. There does not appear to be

any relation here, however, so we may conclude that there are no radiations from above or without which are cut off by the presence of clouds and which affect the conductivity. Large values of the conductivity seem to correspond to large values of atmospheric pressure, but the relation here is probably indirect in nature, as it is difficult to see how such small changes in the pressure could affect appreciably the rate of production, the rate of recombination, or the specific velocities of the ions.

The large mean value of the conductivity found in this work, combined with the uncertainty which exists in regard to the dependence of the ionization of the atmosphere on its radioactivity, makes it interesting to consider the observations of the conductivity from another standpoint. Till recently, it has always been the custom to attribute a large part of the ionization of the atmosphere to the radioactive constituents diffused throughout it. The continual supply of these materials has been regarded as due to the diffusion of radioactive emanations into the atmosphere through the pores of the ground. Since the Pacific, Atlantic, and Indian Oceans are sucessively smaller in size, one would expect any effect on atmospheric phenomena due to the land to be successively greater in the three oceans, in the order named. It is therefore interesting to compare the mean values of the conductivity as found in these three oceans. Table 3 contains these data.

TABLE 3.—*Regarding the conductivity in the different oceans.*

Ocean.	$\lambda \times 10^4$.	No. of days observed.
Pacific.........	2.49	131
Atlantic.......	3.51	187
Indian.........	4.28	15

The influence of the land is markedly shown. The results of this table made it seem worth while to sort all the separate values of the conductivity into two groups, according to the nearness of land and the general direction of the wind which prevailed at the times of the separate observations. In one of these groups, which will be designated as "land wind," have been placed all the values of the conductivity which correspond to winds which had probably passed over large bodies of land within a week. In the other group, designated "sea wind," have been placed the remaining values of the conductivity which correspond to winds which had probably been blowing for a week or more over water. The sorting out was done independently by two persons, and table 4 contains a summary of this analysis. One very large value of the conductivity has been omitted in this calculation.

TABLE 4.—*Effect of land on the conductivity at sea.*

Group.		$\lambda \times 10^4$.	No. of days involved.
Land wind....	1	3.17	124
	2	3.11	129
Sea wind.....	1	2.92	208
	2	2.94	203

The summaries in both tables 3 and 4 support Dr. A. Nippoldt's view, as based upon the *Galilee* observations in the Pacific Ocean in 1907-1908, that the effect of the land is to increase the value of the conductivity as measured at sea.

From a summary of the various results thus far obtained at sea, the following deductions in regard to the mean values of the elements may be drawn: The potential gradient is of the same order of magnitude over the sea as over the land; the radioactivity of the air over ocean areas far removed from land is small, compared to that found over land; and that the ionization over the ocean is at least as large as that found over land.

Investigation of certain causes responsible for uncertainty in the measurement of atmospheric conductivity by the Gerdien conductivity apparatus. C. W. Hewlett. Terr. Mag., vol. 19 (Dec. 1914).

The object of the writer was to test experimentally the behavior of the apparatus under various conditions. It was shown by Dr. Swann that the theory of the apparatus does not necessitate a constancy of the velocity over a cross-section of the air-current, and that, if the potential is below a certain minimum value depending on the total air-flow, the correct value of the conductivity is obtained. By covering up half of the space opposite the fan, a considerable irregularity was produced in the air-flow. For low charging voltages, however, the conductivity was practically the same as without the obstruction. As the voltage is increased beyond a certain point, the measured conductivity, without the obstruction, becomes less than that with it, but this is simply due to the fact that the critical voltage is less with the obstruction than without, owing to the smaller air-flow in the former case.

As the measured conductivity was found to depend upon the presence or absence of the funnel, it was thought advisable to investigate the exact effect of the latter. Certain theoretical considerations point to the conclusion that, in the absence of the funnel, the maximum allowable voltage is reduced owing to the fact that the stream lines of the air which enter the funnel near the edges suffer sharp bends in that vicinity. Experiments were consequently made to determine whether the effect of the funnel was less important for low charging voltages. It was found that for charging voltages of 10, 30, 50, 70, 100, the relation of the conductivity without the funnel to that with the funnel were 0.98, 0.96, 0.98, 0.94, 0.89; hence, the theoretical conclusion that the ratio is practically unity for low voltages, and less than unity for higher voltages, is borne out.

Experiments have also been made to determine the effect of the charge induced on the earthed portions of the apparatus owing to the existence of the potential gradient. It is found that under certain conditions this effect may be considerable.

The usual theory of the Gerdien apparatus neglects the effect of the charge collected by the rod which supports the central cylinder. Experiments were made to measure directly this charge, and it was found to be far from negligible in comparison with that collected by the central cylinder.

In the use of the Gerdien apparatus it is important that the charging potential used shall always be sufficiently low. The most sensitive region of the electroscope supplied with the instruments is usually in the neighborhood of 150 to 200 volts. It has been found, however, that the maximum allowable voltage varies considerably from day to day, presumably owing to variations in the specific ionic velocities. Usually a charging potential of 150 volts is far too high.

The atmospheric potential gradient, and a theory as to the cause of its connection with other phenomena in atmospheric electricity, together with certain conclusions as to the expression for the electric force between two parallel charged plates. W. F. G. Swann. Terr. Mag., vol. 18, pp. 163–184 (1913).

The paper comprises a mathematical discussion of the electrical conditions which would be expected to prevail in the atmosphere, starting with the assumption of a potential which increases with the height above the ground and utilizing the theory of conduction of electricity in gases. It was undertaken with the object of determining how far the main features shown by the atmospheric-electric elements are the logical outcome of the mere existence of a potential gradient in a conducting atmosphere. It is shown that this requires:

(1) That the ratio of the number of positive ions per cubic centimeter at the Earth's surface, to the number of negative ions, shall be greater than unity, a similar result holding for the corresponding dissipation coefficient.

(2) That the above ratio shall increase with the potential gradient.

(3) That neither n_1, the number of positive ions per cubic centimeter, nor n_2, the number of negative ions per cubic centimeter at the Earth's surface, are the same thing as the numbers which, if the atmospheric field were absent, would exist in order to result in a balance between recombination and formation. According to the theory, both n_1 and n_2, near the Earth's surface, should be less than at points high up.

(4) That the atmospheric potential gradient in a homogeneous atmosphere shall decrease with the height in the neighborhood of the Earth's surface.

(5) That there should be an apparent, but not necessarily true, increase of the rate of ionization with the height.

Various other minor speculations and conclusions are also involved.

All of the above conclusions are in harmony with experiment. The calculated quantities are of the same order of magnitude as those found experimentally. This is as much as can be expected in view of the fact that the calculation is restricted to a case where the specific velocities of the positive and negative ions are equal, and the rate of formation of ions is independent of the height. As examples of the kind of variations of the elements prescribed by the theory, the following may be cited: Suppose that the rate of formation of ions is 11 ions per cubic centimeter per second, the specific velocity of each kind of ion 1.6 cm. per second per volt per second, and that the potential gradient, some considerable distance above the ground, is 100 volts per meter. If N is the number of positive or negative ions per cubic centimeter and λ the conductivity far above the ground, the value of the conductivity at a height 3.5 meters above the ground should be $\lambda/1.6$, the number of positive ions being 0.85 N and the number of negative ions 0.40 N. The potential gradient at the Earth's surface would be 2.76 times the value at a great altitude. Rapid variation of the potential gradient should, however, be confined to the lower altitudes, and at an altitude of 10.4 meters the potential gradient should only differ by 1 per cent from its value at infinite altitude when the latter value is 100 volts per meter. In a case where the value of the potential gradient at infinite altitude is 250 volts per meter, the value at an altitude of 26 meters would still only be 1 per cent different from the minimum value. The continual decrease of the potential gradient with altitude up to high altitudes is thus not continued in the present simple form of the theory which assumes the rate of production of ions and specific velocities independent of the altitude.

The above theory was worked out on the assumption that the problem may be treated as equivalent to that of two infinite, oppositely charged plates separated by a large distance. The lower charged plate is the surface of the Earth, and the upper plate may be represented by the highly conductive layers which possibly exist in the higher regions of the atmosphere. Though the case where the plates are near together is of no particular cosmical interest, it is important to notice that the above conclusions would not hold in this case. It turns out, for instance, that if the plates were only 14 centimeters apart, and the potential gradient midway between them were 100 volts per meter, the potential gradient *at* one of the plates would be about 1.0026 times the value midway between them, instead of 2.76 times that value, as in the case where the plates are very far apart. Again, the variations of n_1 and n_2 with the distance from one of the plates follow different laws to those which hold when the distance is very great.

The measurement of atmospheric conductivity, together with certain remarks on the theory of radioactive measurements. W. F. G. Swann. Terr. Mag., vol. 19, pp. 23–37 (1914).

The theory of the method of measuring atmospheric conductivity by noting the alteration of potential of a charged stretched wire surrounded by an earthed net is examined from a mathematical standpoint. The paths of the ions coming to the wire are calculated, and it is shown that, for a net of the size usually employed under ordinary conditions of wind velocity, a practically true value of the conductivity would be obtained if there were no potential gradient. The effect of the potential gradient is to cause a negative charge to appear on the earthed net, however, and in the determination of the conductivity due to the negative ions the charge on the net widens out the paths of the ions, reducing the number which would otherwise enter the net, and reducing consequently the conductivity. The effect becomes most pronounced for small wind velocities. For a case where the component of the wind velocity resolved perpendicular to the wire is as small as 20 cm. per second, and the potential gradient is as high as 260 volts per meter, the measured value of the conductivity would be only about 0.65 of the true value for a potential difference of 200 volts between the wire and netting.

In the second portion of the paper, the theory of the collection of active material by a charged wire is considered, when the wire is exposed in the atmosphere, and formulæ are deduced relating the activity as measured for the wire with the amount of active material per cubic centimeter of air. The effect of that portion of the charge on the wire resulting from the potential gradient is discussed, and it is shown that unless suitable precautions are taken to allow for it, the results may be greatly in error.

The theory of electrical dispersion into the free atmosphere, with a discussion of the theory of the Gerdien conductivity apparatus, and of the theory of the collection of radioactive deposits by a charged conductor. W. F. G. Swann. Terr. Mag., vol. 19, pp. 81–92 (1914).

If a sphere charged with Q units of electricity is exposed to a stream of air moving with uniform velocity over a cross-section, and if n is the number of ions per cubic centimeter of opposite sign to Q, in the air, v the specific velocity of the ions, and e the electronic charge, Riecke has shown that $\frac{-dQ}{dt} = 4\pi Qnev$. The formula has been shown to hold also in the case of an infinitely long wire charged with uniform surface density. In the present paper it is also shown that the formula is quite general, and applies to a conductor of any shape, even when the conductor is not the only charged body in the neighborhood, provided that a certain condition, not of a very restrictive character, is satisfied. The formula is, moreover, true when the air velocity varies over a cross-section.

The formula enables more accurate expressions to be deduced for the flow of electricity to the charged system in certain atmospheric electric instruments than have generally been used. For example, the theory of the Gerdien conductivity apparatus has heretofore been deduced on the assumption that the instrument may be treated as part of two concentric cylinders of infinite length, and moreover neglects the effect of the supporting rod of the central cylinder. The present formula enables a more accurate expression to be immediately obtained, including the effect of the rod. The true expression leads to values of the conductivity 20 per cent different from those calculated on the usual formula, and in some instruments with thick supporting rods the difference has amounted to as much as 40 per cent. The theory further shows that uniformity of velocity over a cross-section is not necessary, and it also leads to a very ready method of determining the limits of applicability of the apparatus.

The theory of the collection of active deposits by a charged wire is discussed in relation to the above theory, certain serious sources of uncertainty are pointed out, and more exact formulæ are deduced.

On certain new atmospheric-electric instruments and methods. W. F. G. Swann. Terr. Mag., vol. 19, pp. 171–185 (1914).

The first instrument described is a modification of the Ebert ion counter. In the usual form of ion counter the central cylinder of the instrument is connected to an electroscope reading up to about 200 volts, and the outer cylinder is earthed. The rate of movement of the fibers of the electroscope when the air flows through the instrument under these conditions is extremely slow, and many minutes are required to obtain a single satisfactory observation. Moreover, during the observation the quantity being measured varies and this may give rise to serious trouble; for instance, in the determination of the specific velocity of the ions by Ebert's method, in which it is necessary for the ionic density to remain constant during two experiments, the variation of the ionic density is often so great as to apparently completely wipe out the quantity measured, or even render it apparently negative. In the instrument described the central cylinder is connected to the fiber of a single-fiber electroscope of the Einthoven type adjusted to a sensitivity of about 20 or 30 divisions per volt. The potential of the fiber is never allowed to depart far from zero potential and the necessary field is obtained by insulating and charging the outer cylinder to about 200 volts. On releasing the fiber from earth it of course starts to move, and the rate of movement can be noted. In order to prevent the charge on the outer cylinder affecting the number of ions coming to the apparatus, it is shielded by another cylinder which is earthed. In order to insure that the charge on the upper edge of the shielding cylinder does not rob the air of ions which should go to the central rod, a special attachment is made to the latter which renders this impossible. The employment of a sensitive electroscope rendered possible by the above scheme enables the ionic density to be determined easily ten or twenty times as rapidly as by the ordinary apparatus. The apparatus may also be used in conjunction with the usual subsidiary attachment for determining the specific velocities of the ions.

The second portion of the paper describes a convenient arrangement which may be employed for determining the radioactive content of the atmosphere by the Elster and Geitel method. It is shown that the rate of collection of active material is proportional to the charge on the collecting wire, and in order to render this a definite quantity depending only on the potential of the charging battery, and independent of the potential gradient, the collecting wire, *A*, is placed on the same equi-potential surface as another wire, *B*, from which it is insulated. *B* is kept at the potential of the air around it by two

radium collectors, and the positive pole of the charging battery is connected to B instead of to earth, as in the usual arrangement. The negative pole of the battery is, of course, connected to the collecting wire, A. In the determination of the activity curve of the wire, the latter is wound on a frame and placed in an ionization chamber as in the Elster and Geitel arrangement. The central rod of the ionization chamber is connected, however, to the fiber of a sensitive single-fiber electroscope of the Einthoven type and earthed. The outer cover of the ionization chamber is insulated and kept charged to 150 volts by Krüger batteries. On releasing the fiber from earth it starts to move at a much more rapid rate than is obtained in the usual method, where the outer case of the ionization chamber is earthed and the central rod of the chamber is charged to a potential far different from that of the earth, necessitating the use of an electroscope of a much less sensitive type. A discussion is given of certain points on the relation between the activity collected by the wire and the radioactive content of the atmosphere. It is not always convenient to deduce the actual amount of active material in the air, but it is suggested that in place of the usual Elster and Geitel unit, which depends upon the particular apparatus used, a more fundamental unit should be employed. A quantity which may conveniently be recorded as a measure of the activity of the air is

$$A = \frac{\kappa}{eVC}\frac{\delta v}{\delta t}$$

where C is the measured capacity of the portion of the collecting wire which is placed in the ionization chamber, V is the potential of the charging battery, κ is the capacity of the ionization chamber, $\frac{\delta v}{\delta t}$ is the initial rate of alteration of potential of the electroscope when the wire is placed in the ionization chamber, and e is the electronic charge.

The third portion of the paper describes a piece of apparatus suitable for obtaining relative values of the potential gradient. A tube, about 8 feet long, is arranged so that it can be turned about its axis. A wire, insulated from it, is stretched along its axis and connected to brass pieces fixed by ebonite plugs in the ends of the tube. One of the brass pieces carries an arm about 50 cm. long. The arm is perpendicular to the axis of the tube and carries at its end a disk. The brass piece at the other end of the wire is connected to a special key. In one position this key earths the insulated system and an electroscope at the same time. On turning the tube slightly the insulated system and the electroscope become disconnected from earth and from each other. On turning the tube 180° from its initital position the insulated system again becomes connected to the electroscope. It is obvious that unless the tube is perpendicular to the equipotential surfaces, the electroscope will show a deflection, and the change of its potential will be proportional to the potential gradient. The instrument was designed specially for work at sea and in this respect possesses two chief advantages. In the first place, good insulation is not vitally important, as is the case with the usual collectors, since it is only necessary for the insulated system to show no leak while it is being turned through 180°. In the second place, the method enables the potential gradient to be measured at an instant, and consequently readings may always be taken at one position of tilt of the vessel during a rough sea. This avoids uncertainty in the meaning to be attached to the results, owing to the dependence of the quantity measured by the instrument on the shape of the surface bounded by the ship and the sea. It is, of course, necessary to standardize the instrument by comparisons with measurements made over a flat surface and free from disturbing influences.

On certain matters relating to the theory of atmospheric-electric measurements. W. F. G. Swann. Terr. Mag., vol. 19 (Dec. 1914).

The earthed portions of pieces of apparatus exposed to the atmospheric potential gradient have to take a negative charge in order that their potential may remain zero. The effect of the charge in modifying the measurements is discussed for various cases. In the Ebert ion counter the effect is to decrease the measured ionic density in the case of the negative ions, while in the case of the positive ions the results are unaffected, though the paths of the ions are of course influenced by the charge. It is shown that the effect is expressible very simply in terms of the charge induced by the potential gradient on the *inside* of the opening where the air enters. By measuring this charge it is possible (knowing the rate of the air-flow) to estimate the order of magnitude of the effect. The effect is greatest of course when the apparatus is mounted on a tall, slender support. It was found by measurement that it might easily amount to 20 per cent of the value of the quantity measured. The analogous effect is discussed for the case of the Gerdien conductivity apparatus, and it is shown that even in the case of the negative ions no error is introduced, provided that the potential of the central conductor is not too high. In fact, the effect of the potential gradient is simply to lower the value of the maximum potential to which it is allowable to charge the central system. In the case of the conductivity of the positive ions, while the ionic paths are influenced, neither the conductivity nor the maximum potential allowable are influenced on the whole.

The effect of making measurements of conductivity on the top of a high tower is discussed in the above light and it is shown that if suitable precautions are taken, the proper conductivity will be obtained for the air at that altitude, in spite of the influence of the charge on the tower. There is an advantage in making measurements on the air far removed from the ground, since the number of ions present are then uninfluenced by the effects due to the potential gradient referred to in the first abstract.

The question of shielding the instruments to protect them from the potential gradient is discussed. It is only in the case of the Ebert apparatus that shielding of this kind is necessary. It is important to ascertain, however, whether the avoidance of charge on the earthed portions of the apparatus by shielding is not counteracted by the effect of the charge on the shield. It is shown that a properly arranged shield is on the whole effective.

Some points with regard to the variation of the specific magnetization of a substance with temperature. W. F. G. Swann. Physic. Rev., ser. 2, vol. 3, p. 485 (1914).

According to the theory of Weiss, the molecular magnetic theory of a solid may be treated on the lines of that for a gas, provided that the applied field H is replaced by $H+H_m$, where H_m is a field which represents the effects of the molecular actions. H_m is assumed to be of the form NI, where I is the intensity of magnetization and N is a constant for the substance.

Weiss has shown that in order to account for the variations of the specific magnetization with temperature above the Curie point, it is necessary to assume that the number of magnetons in a molecule changes abruptly at certain temperatures. In the present communication it is shown that this is not all that is necessary to account for the facts, but that the constant N must also vary abruptly with the temperature and in some cases must even acquire a negative value.

A change in the number of magnetons is usually not accompanied by an abrupt change in the coefficient of magnetization, which fact seems to indicate a tendency on the part of the substance to make a change in the number of magnetons only when the temperature conditions are such that it can do so without altering that part of the energy which is purely magnetic.

ARCHEOLOGY.

Morley, Sylvanus G., Santa Fe, New Mexico. *Research Associate in American Archeology.*

After several conferences in July 1914 with the President of the Institution, Mr. Morley proceeded to Santa Fe to take up the preparation of a work containing descriptions and decipherments of all known Maya texts, which will be so arranged as to be a ready and standard book of reference on Maya chronology.

The Maya hieroglyphic inscriptions, so far as they have been deciphered, deal exclusively with the counting of time either in relation to the Maya calendar or certain astronomical phenomena with which the Mayas were familiar. Especially important are the so-called Initial Series, which fixed dates in the Maya chronological system in such a way that they could not recur, filling all the given conditions, until after a lapse of 374,400 years. During the past five years at least 50 new Initial Series have been discovered which have never been published; and when it is taken into consideration that only about 90 had been previously described, it seems probable that the investigation of the new material already in hand—as contemplated in this research—will shed much light on the whole field of Maya chronology and clear up many existing problems.

Van Deman, Esther B., Rome, Italy. *Research Associate in Roman Archeology.* (For previous reports see Year Books Nos. 9-12.)

The summer months of 1913 were devoted largely to the regular work on methods of Roman concrete construction. During August, however, through the courtesy of the government engineers in charge of the work, the rare privilege was obtained of studying the extensive remains of the ancient monuments in the center of the Viminal hill, which were brought to light by the removal of the modern gardens formerly on that site. The examination was necessarily of a somewhat cursory character, but it was possible to classify and to determine the period of a considerable number of monuments of the early empire as well as of the later republic. Many valuable data concerning the methods of constructing concrete buildings were collected by the examination of these monuments as they were laid bare and during their demolition. A rough plan of the remains seen was drafted, which, except that of the engineers, was the only one made of this important section of the ancient city. This plan will be published later, after the appearance of the official reports.

In September a brief study was made of the remains of the ancient city of Luna, as well as of the marble quarries of Carrara nearby, which

probably represent those from which came the famous Luna marble introduced into Rome by Augustus.

At the suggestion and with the assistance of Dr. Thomas Ashby, Director of the British School in Rome, a careful examination was undertaken of the Anio group of aqueducts, consisting of the Anio Vetus of 272 B. C., the Aqua Marcia of 144 B. C., with the later Tepula and Julia, and the Aqua Claudia and Anio Novus of the time of Claudius. Despite the great length of the courses of these aqueducts and the remote districts in which many of the scattered fragments are to be found, the more extensive groups of remains, several hundred in number, have been studied and partly classified. Of the remains not before identified, the most important belong to the periods of Marcius, and of Augustus, Titus, and Hadrian. The discovery of a new and distinct type of concrete, or pseudo-concrete, in the underground channel of the original Aqua Marcia, is of special significance for the history of that construction, since it represents an earlier stage in its development than has yet been found in any of the dated monuments in the city.

The winter months were devoted almost exclusively to the collection of data concerning the history of concrete construction in general, with a view to the determination of the original sources of the knowledge of this construction, of its first appearance in Italy, as well as of its introduction and early development in Rome. As an aid in determining these questions, several weeks were spent, during March and April, in the region of Cumæ (the ancient center of many Greek and Oriental influences) and at Pompeii. It seems clear from this investigation, as Dr. Richard Delbrück holds in his work on Hellenistic monuments, that southern Italy, during the earlier period, stood to Rome in the relation of teacher rather than that of pupil. It is no less evident, however, that a partial reversal in their relations took place during the early empire, and that consequently the form of construction established for Rome will serve as a safe basis for future work in that region. At the suggestion of Dr. Ashby, a short time was spent in the vicinity of Beneventum and Foggia, in the examination of the fine concrete remains of a number of bridges and viaducts belonging to the ancient Via Trajana, and to the parts of the Via Appia restored by Hadrian, which, owing to their remoteness from modern lines of travel, are still remarkably well preserved. In their general technique, these structures show a distinct agreement with and dependence upon those of the same period in Rome; but in certain details—notably in the use of broken floor-tiles instead of roof-tiles for facing—they anticipate the technique of the city of Rome by more than a half century. This fact was further confirmed by a subsequent examination of the noted amphitheater of Capua, which was found to belong wholly to the period of Hadrian.

The summer was spent in the final preparation of a general work on the development of Roman concrete construction, which it is hoped

will appear very soon. A number of new monuments or parts of monuments throughout the city have been identified during the year. The most important of these are several new portions of the palaces of Nero and Hadrian on the Palatine, and of Caligula at its foot, as well as a nameless monument of the period of Hadrian on the south side of the upper Sacra Via. The remains of the so-called Temple of the Sacred City have been found to belong almost entirely to the period of Augustus instead of to that of Vespasian, as generally held. An extensive group of monuments in the Forum has been identified, which belongs to the period of Sulla.

Hearty support has been given to the work, during the year, by the older English, German, and Italian archeologists, and valuable assistance has been rendered by students of the British School and of the University of Rome, who have furnished careful descriptions and measurements (made according to the newer methods) of various monuments studied by them.

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Garrison, Fielding H., Army Medical Museum, Washington, District of Columbia. *Preparation and publication of the Index Medicus.* (For previous reports see Year Books Nos. 2–12.)

The Index Medicus for 1913 contains 1,448 pages, 39 pages more than the issue for 1912; and the annual index of the same, issued about July 15, contains 233 pages, 9 more than that of the preceding year. The seven monthly numbers issued to date (1914) consist of 841 pages, covering the months January to July. The sudden advent of the war in Europe makes it highly probable that, after a certain date, there will be little medical literature from the continent of Europe for some time. In the Surgeon General's Library at Washington this is already true, so far as the periodical literature of France, Austria, Russia, and Belgium is concerned, and perhaps a temporary falling off in the medical periodicals of England, Germany, and Italy may also be noticeable during the war. This being so, the monthly numbers of the Index Medicus may be correspondingly diminished in size.

There have been no changes in the scheme of classification, except that the subtitle "Deficiency Diseases" has been added to the general concept of disordered metabolism, "beri-beri" and pellagra having been transferred to this class from "Intoxications."

CHEMISTRY.

Acree, S. F., Johns Hopkins University, Baltimore, Md. *Continuation of the study of catalysis and tautomerism.* (For previous reports see Year Books Nos. 4–12.)

Our researches during the last nine years have proven conclusively that both the ions and the non-ionized forms of acids, bases, and salts are chemically active, and this theory has now been adopted and used by a large number of workers in physical-organic chemistry. Seventeen articles on this subject have appeared and a monograph is nearly completed. Thirty articles are ready for publication and ten preliminary notices have been prepared. During the past year our investigations have been aided by Dr. C. N. Myers, Dr. W. A. Taylor, Dr. H. A. Lubs, Dr. W. F. Clarke, and Messrs. W. A. Gruse, R. N. Mulliken, M. B. Hopkins, L. S. Pratt, E. C. White, E. H. Wight, F. C. Lee, D. F. Smith, L. G. Wesson, and F. J. LaMotte. The following articles have been sent for publication:

Catalysis. Part XVIII. The Reactions of Both the Ions and the Molecules of Acids, Bases, and Salts. The Reactions of Alkyl Haloids with Phenoxides and Ethoxides. By J. H. Shrader and S. F. Acree.

In this article is presented the reinterpretation of the work of Segaller on the action of *n*-propyl iodide on sodium phenolate at 42.5° and of Hecht, Conrad, and Brückner on the action of methyl iodide on sodium ethylate at 24°. These workers did not use the ionization theory, but interpreted their work by the empirical equation $K'_N - K_N = a \log (V'/V)$, which we have been able to show harmonizes well with our rational equation $K_N = K_i a + K_m (1 - a)$.

On the Reactions of Both the Ions and the Molecules of Acids, Bases, and Salts. On the Conductivity and Ionization of Sodium Ethylate, Potassium Ethylate, Lithium Ethylate, Sodium Phenolate, Potassium Phenolate, Lithium Phenolate, Sodium Phenylthiourazole, Sodium Iodide, Sodium Bromide, and Mixtures of these Electrolytes in Absolute Ethyl Alcohol at 0°, 25°, and 35°. By H. C. Robertson, Jr., and S. F. Acree. Nineteenth Communication on Catalysis.

This article gives the conductivity and ionization of each salt and of their mixtures and a full description of the cells and other apparatus used. There is a full discussion of the isohydric principle, of viscosity, and of the corrections which must ultimately be made on the conductivities in order to obtain the true ionizations in the concentrated solutions. The ionization values given in this article form the basis of all the calculations made in the succeeding articles.

On the Reactions of Both the Ions and the Molecules of Acids, Bases, and Salts. The Reaction of Sodium Ethylate with Ethyl Bromide and Ethyl Iodide in Absolute Ethyl Alcohol at 25°. By E. K. Marshall, Jr., and S. F. Acree. Twentieth Communication on Catalysis.

In this article are given the complete experimental data and it is shown that the evidence can be interpreted on the idea that both the ethylate ion and the non-ionized sodium ethylate react with the ethyl bromide with the velocities $K_i = 0.00576$ and $K_m = 0.00233$ and with ethyl iodide with the velocities $K_i = 0.0120$ and $K_m = 0.00427$.

On Reactions of Both the Ions and Molecules of Acids, Bases, and Salts. The Reactions of Sodium Ethylate with Methyl Iodide in Absolute Ethyl Alcohol at 25°. By H. C. Robertson, Jr., and S. F. Acree. Twenty-first Communication on Catalysis.

In this article are given all the reaction velocities and the conductivities and it is shown that both the ethylate ion and the non-ionized sodium ethylate react with the methyl iodide with the velocities $K_i = 0.127$ and $K_m = 0.0596$.

On the Reactions of Both the Ions and the Molecules of Acids, Bases, and Salts. A Reinterpretation of the Reactions of Sodium Methylate and Sodium Ethylate with 1, 2-Dinitrobenzene, 1, 2, 4–Dinitrochlorbenzene, and 1, 2, 4-Dinitrobrombenzene. By S. F. Acree. Twenty-second Communication on Catalysis.

In this article the writer has shown that the data of Bruyn, Lulofs, and Steger can be reinterpreted as a reaction of the dinitrobenzene and of the halogenated dinitrobenzene with both the methylate (ethylate) ions and the non-ionized sodium methylate (ethylate).

The work on the theory of the tautomerism of the phenolphthaleins has been advanced very materially by Mr. E. C. White, who has found in phenolsulphonphthalein a substance which nearly ideally fits the requirements for this study. According to the former theory of others, phenolphthalein, which is colorless and practically entirely in the lactoid state (A), is in equilibrium with a trace of the quinoid form (B), which changes into a quinoid monobasic salt (C), the quinone group being responsible alone for the color change.

$$\underset{\text{(A)}}{(C_6H_4COO)\,C\,(C_6H_4OH)_2} \rightleftharpoons \underset{\text{(B)}}{(HOOCC_6H_4)\,C\,(:C_6H_4:O)\,(C_6H_4OH)} + NaOH \rightleftharpoons$$

$$\underset{\text{(C)}}{(NaOOCC_6H_4)\,C\,(:C_6H_4:O)\,(C_6H_4OH)} + H_2O + NaOH \rightleftharpoons$$

$$\underset{\text{(D)}}{(NaOOCC_6H_4)\,C\,(:C_6H_4:O)\,(C_6H_4ONa)} + 2H_2O$$

According to our theory (C) is only faintly colored and must first react with more alkali and form the dibasic *quinonephenolate* salt (D) before the *chief* color change occurs. Up to this time it has been impossible to observe both of these steps taking place successively because the COONa group of (C) greatly suppresses the ionization of the COOH group of (B) and makes it possible for the NaOH to be partitioned between the COOH groups and OH groups and give rise to (C) and (D) simultaneously.

Phenolsulphonphthalein is red in the solid state and yellow in solution and hence exists appreciably in both forms (E) and (F). When sodium hydroxide is added to this

$$\underset{\text{(E)}}{(C_6H_4SO_3)\,C\,(C_6H_4OH)_2} \rightleftharpoons \underset{\text{(F) yellow}}{(HO_3SC_6H_4)\,C\,(:C_6H_4:O)\,(C_6H_4OH)} + NaOH \rightleftharpoons$$

$$\underset{\text{(G) yellow}}{(NaO_3SC_6H_4)\,C\,(:C_6H_4:O)\,(C_6H_4OH)} + H_2O + NaOH \rightleftharpoons$$

$$\underset{\text{(H) deep red}}{(NaO_3SC_6H_4)\,C\,(:C_6H_4:O)\,(C_6H_4ONa)} + 2H_2O$$

solution, the *yellow* quinoid form (F) is changed into the *yellow* monobasic salt (G) alone until about 85 per cent of the phthalein is neutralized; then the *yellow* monobasic salt (G) is changed into the *deep red* dibasic salt (H). The chief source of color, then, is shown to be the dibasic *quinonephenolate* salt (H) and not the monobasic *quinone* salt (F), as assumed formerly by others. This experiment is so striking that it can never be forgotten by anyone interested in the theory of indicators. We are making a full study of the affinity and equilibrium constants of the acid and salts by physical-chemical and colorimetric methods and are investigating the chlor, brom, iodo, and other derivatives, and the corresponding phthalins.

Further work by Dr. H. A. Lubs and Mr. E. Hyatt Wight on the tautomerism of the urazoles has shown that the 1-phenyl-3-methylsulphon-5-oxyurazole displays the widest range of tautomeric possibilities yet discovered. The silver salt and ethyliodide give nearly pure O-ester, whereas the sodium salt and ethyliodide give nearly pure N-ester. A large number of salts and esters have been investigated and full reports will appear later.

Dr. W. F. Clarke has continued further investigations on the hydrogen electrode, calomel electrode, and contact potential and has shown that he can reproduce the electrodes to within 0.00001 volt.

Baxter, Gregory P., Harvard University, Cambridge, Massachusetts. *Determination of atomic weights.* (For previous reports see Year Books Nos. 3–12.)

At the beginning of last October the T. Jefferson Coolidge Jr. Memorial Laboratory for quantitative analysis was opened, and all the researches carried on with the assistance of this grant were conducted in this laboratory under conditions ideal for the purpose as regards cleanliness and convenience. The various investigations were as follows:

The Atomic Weight of Lead.

This research is a continuation of work begun by Mr. Worsham and Dr. Thorvaldson, and taken up anew somewhat over a year ago by Mr. Fred L. Grover (see Year Books Nos. 8, 9, and 12). Mr. Grover has completed the analysis of lead bromide, as described in Year Book No. 12. The results are given in the table on the next page.

A preliminary series of twelve closely agreeing analyses of lead bromide made by Dr. Thorvaldson yielded an average result identical with Mr. Grover's. Because Dr. Thorvaldson's work was essentially pioneering, the detailed data are not given here.

Mr. Grover also undertook the analysis of lead chloride, since the earlier results obtained by Baxter and Wilson (see Year Book No. 6) are somewhat lower than those yielded by the bromide analyses. Under certain conditions (high concentration and high temperature) lead chloride which has been crystallized from slightly acid solution or fused in an atmosphere of dry hydrochloric-acid gas was found to yield an insoluble basic chloride by hydrolysis when dissolved in water.

In this respect lead chloride resembles lead bromide, and the difficulty was avoided as in the case of the bromide by solution in slightly acidulated water. After fusion in an atmosphere of pure dry hydrochloric-acid gas the salt was analyzed by comparison with silver and by weighing the silver chloride formed.

SERIES I.

Ag = 107.880		PbBr$_2$: 2Ag	Br = 79.916	
Fusion atmosphere.	Corrected weight of PbBr$_2$ in vacuum.	Corrected weight of Ag in vacuum.	Ratio PbBr$_2$: 2Ag	Atomic weight of lead.
	grams.	*grams.*		
H_2+ HBr....	5.27845	3.10271	1.70124	207.23
H_2+ HBr....	2.65094	1.55822	1.70126	207.23
N_2+ HBr....	4.08410	2.40104	1.70097	207.17
N_2+ HBr....	4.97468	2.92473	1.70090	207.15
N_2+ HBr....	4.05541	2.38398	1.70111	207.20
N_2+ HBr....	3.44139	2.02290	1.70122	207.22
N_2+ HBr....	5.17388	3.04158	1.70105	207.19
N_2+ HBr....	3.84497	2.26022	1.70115	207.21
H_2+ HBr....	4.30513	2.53086	1.70105	207.19
H_2+ HBr....	4.53445	2.66549	1.70117	207.21
N_2+ HBr....	5.78437	3.40044	1.70107	207.19
N_2+ HBr....	4.87079	2.86337	1.70107	207.19
N_2+ HBr....	6.28446	3.69447	1.70104	207.19
N_2+ HBr....	4.74639	2.79011	1.70115	207.21
N_2+ HBr....	6.82424	4.01148	1.70118	207.21
N_2+ HBr....	6.53689	3.84274	1.70110	207.20
Br_2+ HBr....	4.10098	2.41088	1.70103	207.18
Br_2+ HBr....	2.64256	1.55352	1.70101	207.18
Br_2+ HBr....	6.30684	3.70718	1.70125	207.23
Average...	....	....	1.70111	207.20

SERIES II.

PbBr$_2$: 2AgBr				
Fusion atmosphere.	Corrected weight of PbBr$_2$ in vacuum.	Corrected weight of AgBr in vacuum.	Ratio PbBr$_2$: 2AgBr	Atomic weight of lead.
	grams.	*grams.*		
N_2+ HBr...	4.05541	4.15017	0.977167	207.18
N_2+ HBr...	3.44139	3.52224	0.977046	207.14
N_2+ HBr...	5.17388	5.29489	0.977129	207.17
N_2+ HBr...	3.84497	3.93446	0.977255	207.22
H_2+ HBr...	4.30513	4.40616	0.977073	207.15
H_2+ HBr...	4.53445	4.64048	0.977151	207.18
N_2+ HBr...	5.78437	5.91976	0.977129	207.17
N_2+ HBr...	4.87079	4.98466	0.977156	207.18
N_2+ HBr...	6.28446	6.43124	0.977177	207.19
N_2+ HBr...	4.74639	4.85708	0.977211	207.20
N_2+ HBr...	6.82444	6.98381	0.977151	207.18
Br_2+ HBr...	4.10098	4.19791	0.976910	207.09
Average, omitting the last analysis..			0.977150	207.18
Average of Series I and II.........			....	207.19

Because of the great interest attached to the supposed relation of lead to radioactive change, and because Richards and Lembert and others have found the atomic weight of radioactive lead to be lower than that of ordinary lead, material from widely different geographical sources was examined. The various specimens were all purified in the same way, by several crystallizations as nitrate and several as chloride. Spectrographic examination in the visible and ultra-violet regions failed to show the slightest difference between any of the samples.

SERIES III.

Ag = 107.880		$PbCl_2$:2Ag	Cl = 35.457		
Mineral.	Source.	Corrected weight of $PbCl_2$ in vacuum.	Corrected weight of in Ag vacuum.	Ratio $PbCl_2$: 2Ag	Atomic weight of lead.
		grams.	*grams.*		
Unknown.....	Commercial lead nitrate	5.63567	4.37200	1.28904	207.21
		5.58730	4.33427	1.28910	207.22
		6.86319	5.32401	1.28910	207.22
Average...	....	....	....	1.28908	207.22
Cerussite......	New South Wales......	6.25884	4.85584	1.28893	207.19
		5.25882	4.07933	1.28914	207.23
Average...	....	....	....	1.28904	207.21
Cerussite......	Commern, Eifel Mts., Germany.	5.73434	4.44857	1.28903	207.21
		4.17445	3.23862	1.28896	207.19
Average...	....	....	....	1.28900	207.20
Galena........	Joplin, Missouri........	4.70770	3.65223	1.28899	207.20
		4.20222	3.25968	1.28915	207.23
Average...	....	....	....	1.28907	207.22
Cerussite......	Wallace, Idaho.........	7.04688	5.46691	1.28901	207.20
		5.88935	4.56868	1.28907	207.22
Average........................		....	....	1.28904	207.21
Average of all chloride analyses.....		....	....	1.28905	207.21

Furthermore, the original minerals in no case gave any indication of radioactivity. This similarity of the different specimens is fully borne out by the results of the chloride analyses, as shown in the table.

The outcome of the investigation in its present stage is obviously that ordinary lead does not vary in atomic weight to an extent capable of detection by the most accurate analytical methods, and that the atomic weight of lead is not far from 207.20 (Ag = 107.880).

Further work upon the atomic weight of lead is planned with material from still different sources, and by a radically different analytical method.

The Atomic Weight of Praseodymium.

Mr. O. J. Stewart has completed the analysis of the various specimens of praseodymium chloride, the purification of which has already been briefly described in Year Book No. 12. The purity of the different fractions was further investigated. In none of the fractions could neodymium be detected by examination of either the absorption spectrum or the spark spectrum, although it was found possible, by

Series I.

Ag = 107.880	$PrCl_3:3Ag$		Cl = 35.457	
Fraction.	Corrected weight of $PrCl_3$ in vacuum.	Corrected weight of Ag in vacuum.	Ratio $PrCl_3:3Ag$	Atomic weight of praseodymium.
	grams.	*grams.*		
3474........	7.66554	10.03129	0.764163	140.942
3474........	8.78959	11.50311	0.764105	140.924
3474........	5.01155	6.55897	0.764075	140.915
Average...	....	....	0.764114	140.927
4383........	6.04235	7.90820	0.764061	140.910
4383........	6.14745	8.04563	0.764073	140.914
Average...	....	....	0.764067	140.912
4381........	6.32550	8.27886	0.764054	140.908
4381........	5.12982	6.71359	0.764095	140.921
4381........	4.59463	6.01332	0.764075	140.915
4381........	4.77556	6.24994	0.764096	140.921
Average...	....	....	0.764080	140.916
4379........	5.96661	7.80908	0.764060	140.910
4379........	6.87536	8.99824	0.764071	140.914
Average...	....	....	0.764066	140.912
4377........	5.73602	7.50707	0.764082	140.917
4377........	4.64585	6.08029	0.764083	140.917
Average...	....	....	0.764083	140.917
4374........	6.85492	8.97148	0.764078	140.915
4374........	8.01711	10.49250	0.764080	140.916
4374........	6.17044	8.07425	0.764612*	140.958
4374........	6.90040	9.03064	0.764110	140.926
4374........	7.08498	9.27274	0.764066	140.912
4374........	5.81309	7.60811	0.764065	140.912
Average, omitting starred analysis.			0.764080	140.916
4371........	6.20845	8.12541	0.764078	140.915
4371........	7.07595	9.26045	0.764104	140.924
Average...	....	....	0.764091	140.919
4368........	5.77646	7.56000	0.764082	140.917
4368........	5.72002	7.48596	0.764097	104.923
Average...	....	....	0.764090	140.920

means of the absorption spectrum, to detect with ease 0.05 per cent of neodymium in praseodymium material. In some of the fractions the cerium content was at least as low, although others were found to contain perceptible quantities of the latter element. The presence of cerium is, however, less serious than the presence of neodymium, since the atomic weight of cerium lies far nearer that of praseodymium than does the atomic weight of neodymium.

SERIES II.

$PrCl_3 : 3AgCl$

Fraction.	Corrected weight of $PrCl_3$ in vacuum.	Corrected weight of AgCl in vacuum.	Ratio $PrCl_3 : 3AgCl$	Atomic weight of praseodymium.
	grams.	*grams.*		
3474	4.12851	7.17915	0.575070	140.915
3474	6.91605	12.02520	0.575130	140.941
3474	7.66554	13.32936	0.575088	140.922
3474	5.01155	8.71348	0.575141	140.950
Average			0.575107	140.932
4383	6.04235	10.50735	0.575059	140.911
4383	6.14745	10.69042	0.575041	140.904
Average			0.575050	140.908
4381	6.32550	10.99847	0.575122	140.939
4381	4.59463	7.98909	0.575111	140.934
Average			0.575117	140.936
4379	5.96661	10.37533	0.575073	140.918
4379	6.87536	11.95497	0.575102	140.930
Average			0.575088	140.924
4374	6.85492	11.91764	0.575190	140.967
4374	8.01711	13.93942	0.575139	140.945
4374	6.17044	10.72822	0.575154	140.954
4374	6.90040	11.99853	0.575102	140.930
4374	7.08498	12.32003	0.575079	140.919
Average			0.575133	140.943
4371	6.20845	10.79543	0.575100	140.928
4371	7.07595	12.30384	0.575100	140.928
Average			0.575100	140.928
4368	5.77646	10.04393	0.575119	140.937
4368	5.72002	9.94637	0.575081	140.921
Average			0.575100	140.929
Average of Series I				140.918
Average of Series II				140.933
Average of Series I and II				140.925

It was definitely proved by direct analysis that the insoluble substance formed when praseodymium chloride is fused in a current of hydrochloric-acid gas is a basic chloride instead of an insoluble modification of the chloride, as was supposed at first. By careful drying of the chloride previous to fusion, and by efficient drying of the hydrochloric-acid gas in which the salt was fused, the quantity of insoluble substance was always kept as low as a few tenths of a milligram, and in some cases none whatever could be seen. In any case the error involved is very small.

The analyses were carried out in the usual way by comparison of the anhydrous salt with pure silver and by weighing the silver chloride. The results of the analyses are shown in the tables. Fraction 3474 was the purest fraction in one of the later series of crystallizations of the double ammonium nitrate. Fraction 4383 was the most, Fraction 4368 the least soluble of the last series.

The close similarity of the different fractions is very satisfactory in showing that, so far as fractional crystallization of the double ammonium nitrate is concerned, no further separation or purification of the praseodymium is to be expected. The atomic weight of praseodymium seems to be very close to 140.92, a value 0.3 unit higher than the one adopted by the International Committee on Atomic Weights, but in fair agreement with some of the most recent work upon this constant.

The Atomic Weight of Neodymium.

Mr. Stewart also made additional analyses of the fractions of neodymium chloride previously analyzed by Mr. Whitcomb (see Year Book No. 11). As in the case of praseodymium chloride, the neodymium chloride, even if very carefully dehydrated by efflorescence at low temperatures, when fused in dry hydrochloric-acid gas frequently yields a very small proportion of insoluble material, which Mr. Stewart proved by direct analyses to be the basic chloride. In the analyses of neodymium chloride made by Mr. Stewart this difficulty was avoided. The following table compares the results of the two experiments:

Fraction.	Whitcomb.	Stewart.	Average.
1+2+3.....	144.293	144.305	144.299
4+5........	144.278	144.287	144.283
6+7........	144.283	144.270	144.277
8+9........	144.271	144.262	144.267
10+11.......	144.272	144.268	144.270
12+13.......	144.262	144.250	144.256
14+15.......	144.262	144.250	144.256

As has already been stated (Year Book No. 11), Fraction 1+2+3 contains a trace of samarium, which would raise the apparent atomic weight of neodymium, while Fractions 12 to 15 contain praseodymium,

which would lower it. As soon as these impurities can be quantitatively estimated, the research will be completed. As it is, the results certainly support the final corrected value obtained by Baxter and Chapin, 144.275.

THE ATOMIC WEIGHT OF CADMIUM.

In several recent investigations Hulett and his collaborators have obtained values for the atomic weight of cadmium agreeing fairly closely at 112.3, by depositing electrolytically, in a mercury cathode, the metal in hydrated and anhydrous cadmium sulphate and anhydrous cadmium chloride and bromide, and by comparison of cadmium deposited in mercury with an electrolytic silver deposit obtained simultaneously. The above value is more than 0.1 unit lower than the one obtained by Baxter, Hines, and Frevert by the determination of the

$Cd : CdCl_2$		Cl = 35.457	
Weight of $CdCl_2$ in vacuum.	Corrected weight of Cd in vacuum.	Ratio $Cd : CdCl_2$	Atomic weight of cadmium.
grams.	*grams.*		
6.08568	3.73172	0.613200	112.420
4.20492	2.57864	0.613248	112.443
5.36195	3.28812	0.613232	112.436
7.50507	4.60219	0.613211	112.426
6.71596	4.11838	0.613223	112.432
5.91551	3.62764	0.613248	112.441
3.14426	1.92795	0.613165	112.405
2.26743	1.38997	0.613016	112.334
5.93495	3.63961	0.613250	112.445
5.49322	3.36806	0.613129	112.390
7.58701	4.65175	0.613119	112.383
4.07400	2.49817	0.613200	112.423
6.04110	3.70499	0.613296	112.466
5.98708	3.67095	0.613143	112.392
9.00005	5.51871	0.613187	112.415
8.57294	5.25679	0.613185	112.415
6.56899	4.02803	0.613190	112.417
7.12956	4.37171	0.613180	112.411
7.76286	4.76007	0.613184	112.413
Average.........		0.613190	112.416

halogen in the fused chloride and bromide. So large a discrepancy was disturbing, and therefore Mr. M. L. Hartmann undertook the electrolytic determination of cadmium in anhydrous cadmium chloride.

In the first place, a special electrolytic cell was devised, constructed of glass, with platinum cathode and anode permanently fused into the walls. The cell was first weighed with a charge of mercury; then a quartz boat, in which a weighed amount of cadmium chloride had been fused, was introduced and covered with water. After a current of electricity had been passed through the solution until practically all the cadmium was deposited in the mercury, the amalgam was washed with water and alcohol, dried in a vacuum, and reweighed. The washings

were collected and evaporated in a quartz dish and a small residue of cadmium salt was converted to sulphate and weighed. Complete deposition of the cadmium was never secured.

The advantages of this cell were its small size, the fact that any platinum dissolved by the chloride liberated at the anode was quickly deposited upon the cathode, so that no loss occurred, and the fact that no transference of material was involved, since the boat containing the fused salt was introduced bodily into the cell, to be removed when electrolysis was complete.

The cadmium material was purified in various ways: by electrolysis with a dissolving anode, by fractional precipitation with hydrogen sulphide, by crystallization of cadmium bromide, and always finally by crystallization of the chloride. The purity of the various samples was followed by photography of the spark spectrum in the visible and ultra-violet regions.

The result is in exact agreement with the earlier one of Baxter, Hines, and Frevert, obtained by determining the halogen in the anhydrous chloride and bromide, 112.417. It is difficult to account for the discrepancy between our electrolytic results and those of Hulett.

Mr. Hartmann and Mr. M. R. Grose have extended the research to the determination of the cadmium in cadmium bromide, and their preliminary results confirm the value obtained from the chloride.

The method in general has proved satisfactory far beyond expectation as regards both accuracy and speed, and seems capable of application to many other metallic halides. It is planned to do this as soon as possible. A portion of the apparatus used in this research was provided by a grant from the Elizabeth Thompson Science Fund.

The Atomic Weight of Arsenic.

Mr. G. L. Wendt continued the investigation upon the reduction of arsenic trioxide by iodine pentoxide (see Year Book No. 11), but owing to new difficulties no further evidence is ready for presentation.

The Vapor Pressure of Iodine.

Mr. M. R. Grose investigated the vapor pressure of iodine by the "air-current" method, at temperatures from 50° to 95°, with the results shown herewith.

Temp.	Vapor pressure.
50°	2.153
55°	3.067
60°	4.282
65°	5.960
70°	8.188
75°	11.21
80°	15.09
85°	20.24
90°	26.79
95°	35.22

A curve plotted with these results joins very satisfactorily with curves drawn from the results of Baxter, Hickey, and Holmes, up to 50°, and those of Ramsay and Young, which are dependable to temperatures somewhat below 100°.

Mr. C. F. Hawkins was able to prove experimentally that arsenic trioxide adsorbs no weighable amount of air on its surface. This is the third substance that has been especially investigated from this point of view in the Harvard Laboratory, and in no case has adsorption of air been detected.

Mr. Hawkins also determined the densities of several of the salts employed in the foregoing investigations in order that vacuum corrections might be applied.

Specific gravities referred to water at 4°.				Cubical coefficients of expansion.		
	0°	25°	50°		0° to 25°	25° to 50°
$PbCl_2$....	5.898	5.885	5.873	$PbCl_2$....	0.00009	0.00008
$PbBr_2$....	6.678	6.661	6.646	$PbBr_2$....	0.00011	0.00009
$NdCl_3$....	.....	4.020	.....	....	....	....
As_2O_3....	3.874	3.863	3.852	As_2O_3....	0.00011	0.00011

Mr. Charles Wadsworth, 3d, determined the changes in volume which takes place during the solution of several alkali halides in ethyl alcohol and pyridin at temperatures from 0° to 50° and at widely varying concentrations, and in water at 75° and 95°. Mr. A. B. Haw investigated mercuric chloride in the same way. Both researches supplement earlier work on the subject in this laboratory and the results do not conflict with the hypothesis proposed as to the causes of the observed effects.

Mr. J. E. Lansing eliminated several sources of error in the "air-current" method for determining the aqueous pressure of hydrated salts, and obtained concordant results for several substances at several temperatures.

Detailed accounts of the foregoing researches are being prepared for publication and will soon appear in various scientific periodicals.

Jones, Harry C., Johns Hopkins University, Baltimore, Maryland. *Construction of a diffraction grating as an aid in the prosecution of researches under the auspices of the Institution;* also, *Continuation of investigations on the absorption spectra of solutions and on the conductivity and dissociation of electrolytes in water and in non-aqueous solvents at different temperatures.* (For previous reports see Year Books Nos. 2–12.)

The work on the absorption spectra of solutions, which has been in progress continually in the laboratories of the Johns Hopkins University for the past eight years, under grants from the Carnegie Institution of Washington, has been continued by Dr. Shaeffer and Mr. Paulus. The results of this investigation and of others referred to below will soon appear as Publication No. 210 of the Carnegie Institution of Washington.

It was found last year, by Drs. Guy and Shaeffer, that solutions of non-hydrated, non-absorbing salts are about as transparent as pure water equal in depth to the water in the solution in question. This is what would be expected. On the other hand, it was found that solutions of strongly hydrated salts are more transparent than pure water equal in depth to the water in such solutions. This observation was regarded as important in its bearing on the solvate theory of solution. Combined water had less power to absorb light than free water.

On account of the surprising nature of this apparent fact, it seemed desirable to repeat this phase of our work with improved apparatus and method. This was done by Dr. Shaeffer and Mr. Paulus. They found that solutions of non-hydrated substances were about equally transparent with pure water, except at the bottoms of the absorption bands; there the solutions were as much as 50 per cent more transparent than pure water. This result confirms satisfactorily that obtained last year by Doctors Guy and Shaeffer. This is regarded as probably the strongest evidence thus far obtained for the general correctness of the solvate theory of solution. The only satisfactory explanation of the above result that we can offer is that combined water has less absorption than free water. This might be expected, since the presence of the dissolved substance would probably change the resonance of the water with which it is combined. Further work along this and correlated lines is now in progress. A number of other problems were investigated by Messrs. Shaeffer and Paulus.

Dr. Wightman and Mr. Wiesel studied the conductivities and temperature coefficients of conductivity of a number of organic acids in ethyl alcohol. This is a continuation of the work in non-aqueous and mixed solvents which has been in progress for the past dozen years. It was necessary to design special forms of apparatus for working with alcoholic solutions. The amount of ester formed in each case must be determined and a corresponding correction introduced.

The conductivities of the organic acids in ethyl alcohol were surprisingly small, but the temperature coefficients of conductivity were enormous, amounting to as much as 50 per cent. It is hoped that the further work upon this problem, which is now in progress, will throw some light upon the relation between reaction velocities and equilibrium in alcoholic solutions as compared with solutions in water as the solvent.

Dr. Davis and Mr. Putnam have studied solutions of certain salts in ternary mixtures of water, acetone, and glycerol. They have measured the conductivities and viscosities of the solutions in question, and have compared these with the corresponding values in the pure solvents. These solvents were chosen because acetone has small viscosity and water intermediate viscosity, while the viscosity of glycerol is very high indeed.

The general result in the ternary mixtures of the three solvents is in part what would be expected from the results in the pure solvents in question. Some surprising results were, however, obtained. Further ork along this line is now in progress

Messrs. Lloyd and Watkins are continuing the work on the conductivity, dissociation, and temperature coefficients of conductivity and dissociation of salts in water as the solvent.

Mr. Holmes is studying the different chemical relations of "combined" and "free" water. Results of interest and significance have already been brought to light.

Morse, H. N., Johns Hopkins University, Baltimore, Maryland. *Measurement of the osmotic pressure of solutions.* (For previous reports see Year Books Nos. 2–12.)

The work of the past year has been mainly along three lines, and the greater part of the more important results have already been incorporated with the earlier work and discussed in a monograph which was issued as publication No. 198 of the Carnegie Institution, in June 1914.

The measurement of the osmotic pressure of glucose solutions was completed through 60°, and is now proceeding at 70°. It has been found that between 30° and 60° and, as far as known, at 70°, all the pressures of this substance conform to the law of Gay-Lussac and to that of Boyle for gases. It is to be recalled in this connection that at 0° and 10° previous work had shown the osmotic pressures of glucose solutions to be *excessive* in the sense that at these temperatures the ratios of osmotic to the calculated gas pressures of the solute are all greater than unity. This fact has been tentatively ascribed to a hydration of the solute at low temperatures, which would have the effect of concentrating the solutions.

The osmotic pressures of mannite solutions were measured at 10°, 20°, 30°, and 40°. Mannite was selected because the molecular depressions of the freezing-points of its solutions are normal, *i. e.*, about 1.85°. The ratio of osmotic to the calculated gas pressure of the solute was found in all cases to be unity, showing that, between 10° and 40°, the osmotic pressure of mannite solutions obeys the gas laws.

Much work has also been done during the past year upon certain of the electrolytes, especially upon salts of potassium and lithium. Great difficulty was experienced, as had been expected, from the injurious effect of electrolytes upon the semipermeability of the membranes—an effect which is apparently due to the destruction of their colloidal structure by the cations. Nevertheless, the osmotic pressures of lithium-chloride solutions, ranging in concentration from 0.1 to 0.6 weight-normal, were successfully measured. The pressures found were somewhat in excess of those which could be accounted for by the probable electrolytic dissociation of the solute. For example, the osmotic pressure of the 0.6 weight-normal solution at 30° was 29.54 atmospheres, which would call for a dissociation of the salt amounting to 99.2 per cent. Here again, as in the cases of glucose and cane sugar at low temperatures, the excessive pressures are tentatively ascribed to concentration of the solutions through hydration of the solute.

Much time has been given to the building up and testing of new membranes with a view to discovering, if possible, semipermeable materials which resist the injurious influence of electrolytes more successfully than the ferrocyanides of copper, nickel, and cobalt.

Dr. J. C. W. Frazer and Dr. W. W. Holland have cooperated in the work of the year; and Messrs. E. L. Frederick and A. S. Musselman, in the capacity of volunteers, have rendered valuable assistance.

Noyes, Arthur A., Massachusetts Institute of Technology, Boston, Massachusetts. *Researches upon the properties of solutions in relation to the ionic theory.* (For previous reports see Year Books Nos. 2–12.)

During the past year the lines of research described in the previous reports have been continued.

The measurements, carried out by Mr. R. D. Mailey, on the vapor-pressure, specific volume, and compressibility of water at temperatures from 200° to the critical temperature have now been completed; and the somewhat elaborate computations involved are being made. The results of this investigation will enable a general equation of state for the substance water to be formulated and will make possible an accurate extension to higher temperatures of the "steam tables" used by engineers.

Further studies on the deviations of the behavior of largely ionized substances from that of normal solutes have been made by Dr. C. A. Kraus and Mr. Louis Weisberg, by means of measurements of the electromotive force of concentration-cells.

The investigations of A. A. Noyes on the equilibrium relations of oxidizing and reducing agents have been continued with the help of Mr. C. L. Burdick and Mr. F. H. Smyth. Mr. Burdick has completed the study of the equilibrium of the reaction: Sr (in Hg) + 2NaOH (in water) = 2Na (in Hg) + Sr $(OH)_2$ (in water). His results have indicated the existence in strontium hydroxide solutions of a considerable proportion of the intermediate $SrOH^+$ ion, and have enabled the concentration of it to be approximately estimated. Mr. Smyth has derived values for the oxidation-potential of metallic bismuth against solutions saturated with bismuth oxychloride from determinations of the equilibrium conditions of the reaction: Bi (solid) + 3CuCl (solid) + H_2O = 3Cu (solid) + BiOCl (solid) + 2HCl (in water).

An investigation has been begun, with the help of Mr. A. W. Kenney, on the effect of light on the oxidation potential of uranous-uranyl salts.

Richards, Theodore W., Harvard University, Cambridge, Massachusetts. *Continuation of the exact investigation of atomic weights and other physico-chemical properties of the elements.* (For previous reports see Year Books Nos. 2–12.)

The following investigations were conducted with the help of this grant in the Wolcott-Gibbs Memorial Laboratory of Harvard University, which proved to be peculiarly well suited for the work.

1. Atomic Weight of Lead Obtained from Radioactive Minerals.

This subject was carefully studied with the help of Dr. Max E. Lembert, who came to America from the Grand Ducal Technical School of Karlsruhe for this purpose, on the initiative of Professor Bredig and Dr. Fajans. The latter well-known investigator, as well as Sir William Ramsay, Professor Giesel, Professor Boltwood, Miss Gleditsch, and Mr. Miner, generously provided the experimenters with residues con-

taining lead of this sort. The atomic weight of each of these samples was carefully determined by analyzing the chloride, according to the method as elaborated in this special case by G. P. Baxter and his assistants.[1] It was found that the lead obtained from uraninite, carnotite, or thorianite exhibited a lower atomic weight than ordinary lead, the deficiency amounting in one case to as much as 0.75 unit.

The atomic weight of lead from different sources.

Lead from North Carolina uraninite (Sample R)	206.40
Lead from Joachimstal pitchblende (Samples I and K)	206.57
Lead from Colorado carnotite (Samples D and P)	206.59
Lead from Ceylonese thorianite (Samples H and M)	206.82
Lead from English pitchblende (Sample G)	206.86
Common lead	207.15

The ultra-violet spectrum of a typical specimen appeared to be exactly identical with that of ordinary lead. The necessary inference seems to be that lead from radioactive sources consists of a mixture of at least two substances, of which one is ordinary lead; indeed, even ordinary lead itself may be a mixture. The foreign substance must give the reactions commonly ascribed to lead and must be very difficult if not impossible to eliminate from it by chemical means; for many precautions were taken to purify the samples. This amazing outcome is contrary to our experience with several other elements, notably copper, silver, iron, sodium, and chlorine, each of which has been found to have a constant atomic weight, no matter what the geographical source may have been. The new results on radioactive lead are qualitatively in accord with a recent hypothesis brought forward not long since by Fajans and by Soddy. A note similar to this was published in Science on June 5, 1914, and a preliminary paper, setting forth the detailed methods and results, appeared in the July number of the Journal of the American Chemical Society.

2. Further Investigation of the Silver Voltameter (Coulometer).

With the help of Mr. F. O. Anderegg several unsettled points concerning the silver coulometer as a measure of electrical quantity were studied in detail. In every case the earlier work carried out at Harvard twelve years ago was completely confirmed. It was found that the silver precipitate always occludes more or less mother liquor and that its true weight can not be found until this inclusion is determined and allowed for. It was found also that the anode liquid is unquestionably surcharged with silver in a form capable of being deposited upon a silver surface, but that this superfluous silver is oxidized in a large volume of solution, or if exposed to the air for any length of time, so that then the phenomenon does not appear. It was found, moreover, that the porous cup surrounding the anode is the most convenient method for removing the error due to the anode liquid, and that Kohlrausch's form does not absolutely accomplish this result. The

[1]Subsidized by the Carnegie Institution of Washington.

contrary indications of others are probably to be ascribed to the fact that they ignored the inclusions in the precipitate, which may seriously complicate the issue. The outcome of the recent investigation shows that the best form of coulometer is that in which the anode is inclosed in a porous cup, the level of the anolyte being kept always below that of the surrounding solution. The silver precipitate should be ignited at a redness just barely visible in a dark room, and a small correction should be applied for the trace of silver remaining from the included mother liquor.

3. The Electrochemical Investigation of Concentrated Thallium Amalgams.

This investigation, begun three years ago, was carried to a much further state of advancement during the past academic year with the help of Dr. Farrington Daniels. Not only were potentials between the various concentrations of liquid thallium amalgams measured with the greatest attainable accuracy, but also heats of dilutions, densities, and heat capacities were studied by new and successful methods. The outcome furnishes a great quantity of exact thermodynamic data concerning the electrochemical behavior of these amalgams, and provides the basis for interesting theoretical discussion. It is hoped that before long this work may be made public.

4. The Heat of Solution of Metals.

With the help of Dr. T. Thorvaldson, the heat of solution of metals was studied in great detail by means of a new and improved method. In the course of this work, because of the unsatisfactoriness of the best standard thermometers, a new thermodynamic method of verifying the temperature scale was worked out in detail, and this furnished a more satisfactory basis for the computation of the present results, as well as other thermochemical results recently secured in this laboratory.

5. Heats of Combustion of Organic Substances.

Another elaborate thermochemical investigation was continued with the help of Dr. H. S. Davis. This concerned the heats of combustion of organic substances. Defects in the older methods were discovered and a series of results obtained which it is believed are the most accurate of any thus far executed. Eighteen organic substances were burned quantitatively in an improved adiabatic calorimeter during the course of this work.

6. Heats of Neutralization and Dilution of Strong Acids and Bases.

Dr. A. W. Rowe continued the investigation concerning the heat of neutralization and dilution of strong acids and bases. Lithium and cæsium salts were added to the list, and various data necessary for the rounding out of the thermodynamic treatment were secured. Although this research has already yielded one long paper, much more remains to be published concerning it. It places our knowledge of the heat of neutralization of the acids and alkalis upon an entirely new basis.

7. Further Study of the Compressibility of the Elements.

With the help of Mr. E. P. Bartlett, the study of the compressibility of the elements was continued. Through the courtesy of Dr. Whitney, of the General Electric Company, fine specimens of tungsten, molybdenum, and tantalum were lent to us for the purpose of determining their compressibility, and the constants concerning these elements were determined for the first time. They take precisely the expected places in the curve which was the outcome of the earlier Harvard work subsidized by the Institution. Tungsten has the smallest compressibility of any metal thus far investigated, as would be expected from its exceptionally low volatility. In order to obtain results of the degree of accuracy desired, a new steel piezometer (upon the principle of the glass ones already used in the Harvard work) was constructed and found to yield results much freer from hysteresis-effects than the glass. Not only were these metals determined for the first time, but also the commoner elements, such as mercury, copper, iron, and lead, were studied with a degree of precision not heretofore obtained, and several liquids, among them the liquid amalgams of thallium, were likewise subjected to careful investigation.

8. A New Study of the Surface Tension of Liquids.

In keeping with the plan to study and compare all the important physical properties of typical substances, a new study of the surface tension of liquids was begun with the help of Mr. L. B. Coombs. The tubes in which the levels were compared were subjected to unusual scrutiny and the apparatus was so arranged that readings might be made both in the erect and inverted position as well as from both sides, so that irregular refraction of the glass (which turned out to be a much more serious cause of error than is usually suspected) was effectually eliminated. A number of homologous organic liquids were studied and the results await comparison with the heats of combustion, boiling-points, densities, and other properties now in the process of investigation at this laboratory.

9. Dielectric Constants.

With the help of Dr. J. W. Shipley, the dielectric constants of many of these liquids were studied; and the method of Nernst was improved and made more sensitive for this purpose. Various other properties also, such as boiling-points and melting-points, received careful consideration, and with the help of our accurate temperature scale these were fixed with a degree of precision not heretofore obtained. Among other substances, benzene was obtained from many sources and very carefully purified. Its melting-point was found to be 5.484° C., and it is recommended in connection with the melting-point of ice as a very convenient second temperature for standardizing Beckmann thermometers.

10. Study of Floating Equilibrium.

The study of floating equilibrium, already begun by Dr. J. W. Shipley two or three years ago, was continued with the help of G. W. Harris. He studied especially the behavior of different kinds of glass, their thermal hysteresis, and prepared a table of floating temperatures with various concentrations of hydrochloric acid which will enable anyone to standardize a thermometer in this way. For details the published papers already referred to in the last Year Book should be consulted. The method was found to be extremely sensitive, but with sufficient care it is capable of yielding interesting and significant results.

11. Effects of Isomorphous Impurities on the Transition Temperatures of Crystallized Salts.

With the help of Dr. W. B. Meldrum, the effects of isomorphous impurities on the transition temperatures of crystallized salts were investigated. It was found that the presence of sodium sulphate in sodium chromate raises the transition temperature of the latter salt in a perfectly definite way and a mathematical expression for the effect of increasing quantities was obtained. The details of the phenomena were observed and discussed. The outcome throws light upon the mechanism of solid solution in cases of this sort.

A number of papers concerning some of these and some of the preceding researches were prepared during the winter. Reference to these is to be found in the bibliography. On the whole the outcome of the year's work under this series of grants was perhaps more successful than that of any previous year.

Sherman, H. C., Columbia University, New York, N. Y. *Continuation of the chemical investigation of the amylases.* (For previous reports see Year Books Nos. 11, 12.)

The investigation as previously outlined has been continued during the past year. Progress has been made in the study of the purification of malt amylase, its chemical nature, its amyloclastic and saccharogenic activities under the influence of different electrolytes, and its behavior toward solvents and under the ultra-microscope. Preliminary experiments upon a fungus amylase have also been started and a beginning has been made in the study of methods for the detection and measurement of proteolytic action, to be used in determining whether the amylases of plant origin are possessed of proteolytic power comparable with that which we found in pancreatic amylase in 1912.

The preparations of malt amylase made during the past year show a much higher average activity and a much closer approach to uniformity of power than in any previous work. Nevertheless the maximum activities obtained in 1912–13 and in 1913–14 were in close agree-

ment, three products in each year showing powers between 1,450 and 1,570, new scale, corresponding to 2,200 and 2,350 on Lintner's scale. This marked similarity of power among the six most active preparations acquires additional significance from the fact that they were obtained from four kinds of material—green malt, pale kiln-dried malt, and two malt extracts which had been prepared and concentrated on a commercial scale, but by somewhat different methods. That a marked advance in the average activity of our product did not reveal any increase in the maximum power observed during the previous year, and that the best preparations obtained from different materials and by somewhat different methods show such striking uniformity in diastatic power, suggests that these preparations may be regarded as a fairly definite product approximating the maximum activity obtainable in malt amylase.

Some of the properties of this product were described in our report of last year (and more fully in the Journal of the American Chemical Society, October and November 1913), from observations upon the preparations of high activity obtained in 1912–13. The additional data determined during the past year are again in harmony with Osborne's view as to the chemical nature of this enzyme and in opposition to those of Frankel and Hamburg and of Pribram.

The amylase of malt and that of the pancreas are found to be very similar in their chemical nature, as shown by their qualitative reactions, the percentage of nitrogen which they contain, and the distribution of this nitrogen among the different types of amino-acid radicals present. That they are nevertheless quite distinct substances appears to be established by certain pronounced differences in their behavior. It is found, for example, that malt amylase is much the more stable in pure water solution, while pancreatic amylase is the more stable in 50 per cent alcohol and remains active much longer than the malt amylase when allowed to act upon starch. Moreover, the amylase of malt shows its optimum activity in a slightly acid medium, that of the pancreas in a slightly alkaline medium.

In our earlier work upon malt amylase it appeared to be but little influenced by the addition of electrolytes; but as purer preparations of the malt enzyme were obtained, the necessity for activation by electrolytes became strikingly demonstrable. Malt amylase preparation No. 118, for example, which, when tested with the usual small addition of potassium acid phosphate, showed an activity of 1,340, new scale, equivalent to 2,000 on Lintner's scale, was practically inactive when tested upon purified starch in redistilled water. During the past year much time has been devoted to experiments upon the influence of activators.

Since malt amylase is most active in a slightly acid medium, we have given attention first to acid substances. The optimum activation by

hydrochloric acid, by sulphuric acid, by phosphoric acid, and by potassium acid phosphate is found at about the same hydrogen ion concentration. On account of its fundamental importance, this point is being determined with great care by the electrometric method, although the work is very time-consuming because of the nature of the solutions and the low concentrations of hydrogen ion involved. We plan to follow this by a similar series of experiments upon the influence of neutral electrolytes.

In the experiments already made it has been found that the optimum acidity is much lower for the amyloclastic than for the saccharogenic action of malt amylase. This observation is of special interest in connection with the facts brought out in a comparison of amyloclastic and saccharogenic powers which we published last year (Journal of the American Chemical Society, November 1913). It is planned to make in the future a similar comparative study of the optimum conditions for activation of the amyloclastic and the saccharogenic powers of other amylases. The relationship of these two phases of amylase action to each other and to the proteolytic power which has been found to be such a marked property of the pancreatic amylase bears directly upon fundamental problems of enzyme action in general.

Two papers dealing with the purification and properties of malt amylase and certain differences between the amylases of the pancreas and of malt are now being prepared for publication, and a paper on the influence of acid activators upon malt amylase will probably follow during the winter or spring.

Grateful acknowledgment should be made of indebtedness to several collaborators. Miss M. D. Schlesinger has continued to give her entire time to the investigation; Mr. A. W. Thomas has given almost continuous attention to the problem of activation and especially to the electrometric measurements; and at times, during the year, Professor H. T. Beans, Dr. C. F. Hinck, Mr. P. W. Punnett, and Mr. A. P. Tanberg have cooperated in different parts of the work.

GEOLOGY.

Chamberlin, T. C., University of Chicago, Chicago, Illinois. *Study of fundamental problems of geology.* (For previous reports see Year Books Nos. 2–12.)

The studies of the year have followed the lines set forth in previous reports, especially that of the last year, and in addition progress has been made in putting into the form of definite working tenets for geological use the results reached in the course of these studies. Recent advances in related investigations, especially in tidal, seismic, geodetic, volcanic, and associated lines, have made such radical contributions to earth science as to require important revisions of geologic doctrine. An effort has therefore been made to combine these with the results springing from the planetesimal hypothesis into working concepts for use and for test in concrete application. Since the first outline of the planetesimal view of the origin of the earth was set forth in the Year Book (No. 3, pp. 217–219) the new theory of genesis has been called upon to face unexpected criteria arising from the following discoveries and determinations whose bearings are radical:

1. It has been discovered that Jupiter and Saturn have each a satellite revolving in a retrograde direction in addition to several revolving in a forward direction. These significant discoveries are not only in accord with the planetesimal hypothesis, but are in special concurrence with it in that the orbits of the satellites of retrograde revolutions are more eccentric and otherwise aberrant than those of forward revolutions as anticipated by Moulton's deductions from dynamic considerations.

2. Geodetic determinations by Hayford and others imply that the materials of the earth beneath the great basins are higher in specific gravity than the matter beneath the great elevations and that this difference in specific gravity descends to very considerable depths—at least 70 miles and probably much more. While it is difficult to see how this deep differentiation of specific gravity could have arisen out of a once fluid globe, it is a probable result of a slow accretion differentiated by diastrophic, hydrospheric, and atmospheric action.

3. The discovery of radioactivity has led to studies on the distribution of radioactive substances and to computations as to the heat generated by them, from which it appears probable that radioactive substances are confined mainly to the outer part of the earth. Such a concentration is quite in harmony with the hypothesis of volcanic action that has been deduced from the planetesimal hypothesis which limits internal liquefaction to very local portions of the interior mass which are eutectic in nature and which become specially heated by their content of radioactive matter and are forced by tidal and other internal stresses to work their way to the outer zone essentially as fast

as formed, carrying with them the heat of liquefaction and their radioactive content, and incidentally limiting the rise of the general internal temperature.

4. The second set of seismic waves that traverse the earth after each great earthquake shock are commonly interpreted as transverse in nature. If so they imply that the heart of the earth is composed of elastico-rigid material. The incompatibility of such waves with any continuous couche of liquid material favors the doctrine of solid accretion, though perhaps it does not exclude alternative views.

5. Michelson, Gale, and Moulton have shown by a combined experimental and mathematical investigation that the body tides of the earth coincide closely in phase with the tide-raising body. This leaves no ground for reasonable doubt that the earth body is elastico-rigid in a very high degree. These brilliant and decisive results are in accord with the less complete and exact results of Rebeur-Paschwitz, Ehlert, Kortazzi, Schweydar, Hecker, and Orloff. It is a close inference from these results that the heart of the earth, as well as its outer parts, is essentially a crystalline mass.

These radical determinations and discoveries, arising from diverse quarters, have a convergent force of a high order. They not only lend support to the similar conclusions reached by the cosmogonic and geologic studies to which this report relates, but they give force to the conviction that a revision of the fundamentals of geology is imperative. Moved by this conviction, a series of eight articles under the general title of *Diastrophism and the Formative Processes* has been prepared and published in The Journal of Geology, precedence being given to the most familiar geologic processes. A considerable extension of the series is contemplated. The following are the special titles of the individual articles so far published:

I. Introduction and statement of the basis of the tenets.
II. Shelf-seas and certain limitations of diastrophism.
III. The lateral stresses within the continental protuberances and their relations to continental creep and sea-transgression.
IV. Rejuvenation of the continents.
V. The testimony of the deep-sea deposits.
VI. Foreset beds and slope deposits.
VII. Periodicity of Paleozoic orogenic movements (by Rollin T. Chamberlin).
VIII. The quantitative element in circumcontinental growth.

An article on "The planetesimal hypothesis" has been prepared for Scientia; and a small work on "The origin of the earth" has been prepared for the University of Chicago Science Series. Additional manuscript has been prepared on "The secular climates of the earth."

Vaughan, T. Wayland, U. S. Geological Survey, Washington, District of Columbia. *Study of the stratigraphic geology and of the fossil corals and associated organisms in several of the smaller West Indian Islands.*

The expedition to the northern Leeward and the Virgin Islands was undertaken with three objects in view, all of which are closely related. These were (1) to study the stratigraphic geology of the islands and to make paleontologic collections with special reference to the stratigraphic occurrence of the fossils, so as to establish a proper basis for correlating the geologic formations in the islands with those of the southeastern United States and of Panama; (2) to make additional collections of fossil corals in order to present a more comprehensive and exact account of the successive coral faunas antecedent to the living fauna than was possible with the material already available, and thus trace the history of the development of the coral faunas through Tertiary time up to and including the Recent fauna; (3) to study the physiography of the islands in order to get a basis for making deductions as to how the conditions were brought about under which the living coral reefs have formed. As all of these are subjects to which I had already devoted many years of study, the results were expected merely to supplement those of previous work.

The expedition was rendered possible through a grant from the Carnegie Institution of Washington and through authority given me by the Director of the U. S. Geological Survey to make the studies as a part of my official duties.

I left New York on January 24, 1914, and visited in succession St. Thomas, St. Croix, St. Christopher, Antigua, St. Bartholomew, St. Martin, and Anguilla. I took steamer for New York from St. Christopher and arrived at my destination on March 20. The examinations in the first three of the islands mentioned were cursory, but those in Antigua, St. Bartholomew, St. Martin, and Anguilla were careful and should be classed as detailed geologic reconnaissance. Throughout my journey I was the recipient of much courteous assistance and hospitality, all of which is gratefully acknowledged.

As there is already a valuable literature on most of the islands visited, I did not go into unknown territory. It was expected that the general succession of rocks as described by previous investigators would be found to be correct, and this expectation was realized, except in certain instances some of the igneous rocks are geologically younger than appears from the literature; yet as there are igneous rocks bearing the relations attributed to them, this is only a refinement of detail.

The geologic succession in Antigua, beginning with the oldest rocks, is as follows: (1) old igneous rock, represented by pebbles in the base of (2) stratified volcanic tuffs, sandstones, and clays, with interbedded layers of fresh-water chert; (2) a deposit, at least 400 feet thick, of calcareous clay marl and whitish limestone, which are abundantly fossiliferous, with an extraordinarily rich coral-reef fauna in the lower part;

(3) a variety of igneous rocks which have been intruded into or extruded over (2); (4) Pleistocene non-marine marls.

The geologic succession in St. Bartholomew and St. Martin is lithologically similar to that in Antigua, but it appears that the limestone in each of the three islands is different in age. Anguilla is mostly composed of fossiliferous marl and limestone, which is underlain by igneous rock. The limestone in Anguilla may be of the same age as that in St. Martin. Extensive collections were made in Antigua, St. Bartholomew, and Anguilla, and a small collection was obtained in St. Martin. An attempt was made to procure representatives of the entire biologic assemblage in each formation. The collections from the marine beds, therefore, include calcareous algæ, foraminifera, corals, echinoids, mollusks, brachiopods, and a few crustacea. The collections have already had the requisite preliminary preparatory work done on them, and the fossils have been separated and segregated according to the respective groups, and distributed to specialists for study.

A few general statements may be made regarding the probable geologic age of each of the respective fossiliferous deposits. The limestone and interbedded, stratified tuffs, etc., of St. Bartholomew have been referred to the Eocene by Professor P. T. Cleve. These seem to be the oldest of the sediments studied. They contain one species of coral, *Stylocœnia duerdeni* Vaughan, which also occurs in the Richmond beds of Jamaica. A peculiar fungid genus of corals, to which I have given the name *Antilloseris*, is one of the commonest in St. Bartholomew and is a characteristic fossil of the Cambridge beds of Jamaica. Hill refers both the Richmond and the Cambridge beds to the Eocene. Certain foraminifera, a species of *Orbitoides* found abundantly in St. Bartholomew were collected in beds of reputed Eocene age in Cuba, and a similar species is found interbedded with the Bohio conglomerate in Panama. Another species of *Orbitoides*, a large, stellate form, is similar to one which occurs in beds referred to the Vicksburg formation at Marianna, Florida, and near Bainbridge, Georgia. A large species of *Cerithium* from St. Bartholomew suggests an Eocene age. As some of the *Orbitoides* suggest lower Oligocene as the age, and as some other fossils suggest upper Eocene as the age, the inference seems safe that the horizon is one or the other. As the discrimination between upper Eocene and lower Oligocene in the southeastern United States is not positive, this correlation is fairly definite. The fossils indicate the possibility of correlations between the southeastern United States, Cuba, St. Bartholomew, Trinidad, Panama, and perhaps other areas in Central America.

The next younger fauna is the Antiguan. In 1900 I published a note in Science correlating the coral-reef horizon at the base of the Chattahoochee formation and immediately overlying the Ocala horizon of the Vicksburg formation near Bainbridge, Georgia, with the Antiguan coral-reef beds. This correlation was based on the similarity in facies

of the corals of the two localities and on certain specific identities. The genera of the fossil reef near Bainbridge are all present in Antigua, and a peculiar fungid genus, to which the "*Heliastræa*" *crassolamellata* of Duncan belongs, appears confined to this horizon. It is abundant at both of the last-mentioned localities. A species of *Orbicella*, *O. cellulosa* (Duncan), is abundant at both localities, but the species has also been found at Vicksburg, Mississippi, in beds of lower Oligocene age, and at Tampa, Florida, in a horizon apparently higher stratigraphically than the Bainbridge exposure. This species, however, is of Oligocene age in the United States. Other evidence accords with this correlation, for instance, the presence of *Orthaulax pugnax* Heilprin in the coral-reef bed near Bainbridge and in Antigua. This is a horizon of high importance. It has also been recognized in eastern Cuba and near Lares, Porto Rico. A fauna, either the same or closely related, occurs in eastern Mexico and on the island of Arube.

Apparently the fauna of the marl and limestone on Anguilla is the youngest of the three. No *Orbitoides* were recognized in the field, but a species of *Orbitolites* found abundantly in the Chattahoochee formation at River Junction and at Tampa, Florida, is also abundant in Anguilla. The facies of the coral fauna is similar to that of the fauna of the Emperador limestone, Panama, and a peculiar species of *Orbicella* is common to both. One species of echinoid, *Echinolampas semiorbis* Guppy, is abundant both in Anguilla and in the Emperador limestone. The genus *Orthaulax* and *Amusium lyonii* Gabb are among the Anguillan mollusca. The lower part of the Anguillan marl and limestone closely corresponds to the Emperador limestone horizon of Panama and probably represents the upper part of the Chattahoochee and the Tampa formations of Florida. The upper part of the Anguillan beds, in which *Amusium lyonii* is abundant, perhaps represents a somewhat higher horizon. As already stated, the marl and limestone of St. Martin appear to be of the same age as those of Anguilla.

For the physiographic history of the islands, in its bearing on the locus of the living coral reefs, reference may be made to the Bulletin of the American Geographical Society, June 1914.

HISTORY.

Bandelier, Adolf F., New York, N. Y. *Completion of a documentary history of the Rio Grande Pueblo Indians of New Mexico.* (For previous reports see Year Books Nos. 11, 12.)

From November 1 to December 18, 1913, Dr. Bandelier worked at the archives in Seville, Spain, making copies and extracts of manuscripts needed for the "History of the Rio Grande Pueblos," to be prepared under a grant from the Carnegie Institution of Washington. Shortly afterwards he became ill and unable to work, and died on March 18, 1914.

Osgood, Herbert L., Columbia University, New York, N. Y. *Completion of an institutional history of the American colonies during the period of the French wars.* (For previous reports see Year Books Nos. 11, 12.)

Dr. Osgood reports that his work on Institutional History of the American Colonies has steadily progressed during the year. Near the close of May he sailed for London, where he worked in the Public Record Office, but this work was afterwards interrupted by the conditions produced by the war. However, the most important part of the material had already been obtained. Dr. N. D. Mereness collected material at Baltimore and Washington until the close of March.

LITERATURE.

Bergen, Henry, Brooklyn, New York. *Completion of preparation for publication of the text of Lydgate's Fall of Princes.* (For previous reports see Year Books Nos. 11, 12.)

During the year 1914 progress has been made in the preparation for the press of Lydgate's Fall of Princes, by collating it with the manuscript in the John Rylands Library at Manchester, as well as by finishing the work of copying the text and collating it with two British Museum manuscripts. The time from July 20 until the winter of 1914 is being given to the completion of the glossary and revision of the bibliographical introduction to his edition of Lydgate's Troy Book.

MATHEMATICS.

Morley, Frank, Johns Hopkins University, Baltimore, Maryland. *Application of Cremona groups to the solution of algebraic equations.* (For previous reports see Year Books Nos. 9–12.)

During the past year two papers on restricted systems of equations were prepared by Professor A. B. Coble (American Journal of Mathematics, April 1914 and October 1914).

Ideas and material were developed for a series of papers on Cremona groups associated with discrete sets of points and the relation of the form problem connected with these groups to the solution of algebraic equations. A general algebraic background is thus outlined for the solution not only of the general equation of the nth degree, but also for a number of special equations, such as that determining the lines of a cubic surface. This investigation when completed will bring to a logical conclusion the problem mentioned in the original application for this grant. Important lines of further research suggest themselves. One is a novel series of infinite discontinuous groups which appear both in Cremona and in collineation form. A second is a very promising relation between the n-point sets and theta-modular functions.

MATHEMATICAL PHYSICS.

Moulton, F. R., University of Chicago, Chicago, Illinois. *Investigations in cosmogony and celestial mechanics.* (For previous reports see Year Books Nos. 4, 5, 8–12.)

The unpublished investigations of the past year are as follows:

(1) *On the stability of Jupiter's eighth satellite.*—G. W. Hill proved, by using the surfaces of zero relative velocity connected with Jacobi's integral, that the moon can never recede beyond a determinate finite distance from the earth. A similar discussion shows that all the remaining known satellites in the solar system, except possibly J VIII, are permanently attached to their respective primaries. Hill's criterion of stability is not applicable to J VIII, hence other methods must be used.

The stability or instability of a periodic orbit has definite meaning capable of mathematical formulation. It is shown that this can be used to determine the nature of the stability of a neighboring non-periodic orbit. In examining the question of the stability of a periodic orbit it is necessary to determine the characteristic exponents of the solutions of certain linear differential equations having periodic coefficients. It is shown how to do this by a relatively simple process which avoids certain lengthy transformations of variables, the expansion of numerous functions in Fourier's series, and the use of infinite determinants.

A retrograde periodic orbit having the period of the retrograde satellite J VIII has been computed, and the character of its stability has been determined three times by the two methods which have been developed. The orbit is very stable. An equally important question is whether or not a direct satellite having this same period would be stable. After much labor, a direct periodic orbit having the period of J VIII was found. The orbit was unstable.

This paper was sent in the early summer to the Monthly Notices of the Royal Astronomical Society.

(2) *An extension of the process of successive approximations for the solution of differential equations.*—The existing methods of solving differential equations, with the exception of the Cauchy polygon process, which is not of practical value, have, in general, only a limited domain of applicability. In practical applications, as well as in certain theoretical discussions, it is important to have means which will furnish the solution in any arbitrary part of the domain of its existence. The processes defined in this paper have this advantage. As an application, they make it possible to lay down a complete logical foundation for the so-called method of mechanical quadratures, which has been extensively employed by Hill and Darwin in discovering periodic orbits of the problem of three bodies.

(3) *Orbits of ejection from one body and collision with another.*—Closed orbits of ejection (that is, those which are orbits of ejection from a body and of collision with the same body) were treated in a paper which was published in the Proceedings of the London Mathematical Society,

series 2, vol. 11, pp. 367–397. The more difficult problem of proving the existence of, and actually finding, those which are orbits of ejection from one body and of collision with another body has now been treated. The cosmogonical applications of these results are to the escape of particles from one celestial mass and their collision with another. Certain of these orbits are the limits of two families of periodic orbits. They are, therefore, important in the problem of determining the relations among the various classes of periodic orbits. It is shown in this investigation that infinitely many distinct orbits of ejection and collision exist and a large number have been computed.

(4) *Periodic orbits of the problem of three bodies.*—In attempting to make a complete study of the periodic orbits of the restricted problem of three bodies and of the relations among them, there has been found reason for suspecting the existence of many new families. Ten new families of these orbits have been shown to exist by actual calculation. The computations, which required the tracing of 156 orbits by mechanical quadratures, were made by Mr. W. L. Hart, without whose efficient assistance so much could not have been accomplished.

METEOROLOGY.

Bjerknes, V., University of Leipzig, Leipzig, Germany. *Preparation of a work on the application of the methods of hydrodynamics and thermodynamics to practical meteorology and hydrography.* (For previous reports see Year Books Nos. 5–12.)

During the past year the preparatory investigations for the working out of the third volume of "Dynamic Meterology and Hydrography" have been continued in different directions. Messrs. Hesselberg and Sverdrup have provisionally carried to an end their investigations on the friction in the atmosphere, and a preliminary communication on their results is contained in Mr. Hesselberg's paper, "Die Reibung in der Atmosphäre." Important progress in other directions is marked by Hesselberg's paper on the motion of the air in the level of cirrus; by Sverdrup's paper on extent sheets of inversion in free atmosphere; and by papers published by Hesselberg and Sverdrup conjointly on the influence of the mountains on the motion of the air along the earth's surface, and on fields of acceleration in case of the simplest air-motions.

The Geophysical Institute of the University of Leipzig has continued the issue of its publications, Series I, "Synoptische Darstellungen Atmosphärischer Zustände," which are worked out according to the methods developed in parts I and II of the previously mentioned work. Students are also instructed at the Institute in the use of these methods, and are taking up meteorological investigations in which they come into application.

The steps taken in the past year by the U. S. Weather Bureau and by the Meteorological Office of London to publish weather charts on which pressure is expressed in C.G.S. units will greatly facilitate the more general use of these methods.

NUTRITION.

Osborne, T. B., and L. B. Mendel, New Haven, Connecticut. *Continuation and extension of work on vegetable proteins.* (For previous reports see Year Books Nos. 3–12.)

In the report for last year an account was given of the nutritive properties of zein, the predominant protein of maize. The studies there reported have been extended and the earlier results confirmed and amplified. This defective protein has proved to be peculiarly suitable as a basis for the solution of certain problems respecting the role of amino-acids in maintenance and growth. Attention has been directed this year to a study of the amounts of tryptophane and lysine required for maintenance and growth. Tryptophane is unquestionably essential for certain as yet indefinable functions associated with nutrition in maintenance alone. One per cent or less of tryptophane, calculated on the protein fed, is sufficient for the physiological needs of maintenance. Similarly, experiments have been conducted to learn the quantities of lysine that must be added to a lysine-free diet before growth is manifested. The animal organism can apparently supply whatever lysine may be needed in the wear-and-tear, or maintenance functions, aside from construction of new tissues, from its body reserves, more readily than it can furnish tryptophane. In illustration an experiment may be cited in which a small rat was maintained, without change in body-weight, over a period of six months on a diet containing as its source of nitrogen only zein and tryptophane. Prolonged maintenance has never been observed when the food yields no tryptophane. Apparently far less lysine than tryptophane is needed where tissue building is excluded.

Aside from a purely theoretical interest there is an important practical aspect to this problem. It has already been pointed out that the amino-acid deficiencies of our zein foods can be made good by supplementing them with suitable proteins, provided these supply enough of the essential amino-acids. Edestin and casein—low in their yield of lysine and tryptophane respectively—can be made far more effective in supplementing zein by adding an extra supply of lysine to the edestin or tryptophane to the casein. The protein economy of nutrition evidently depends largely on securing such a mixture of different proteins of unlike amino-acid make-up as will give a total yield in which these nutrient units are present in ideal proportional relationship to each other.

The expectation that the application of these quantitative features of nutrition to the practice of feeding our domestic animals will be of distinct advantage has already in part been realized by investigations now under way on a large scale in some of the agricultural experiment stations. In this connection we have now found that corn gluten, to which some reference was made in our last report, can be successfully supplemented by small additions of commercial "milk albumin." We

are now experimenting to learn whether crude mother liquors—another by-product obtained from the milk-sugar manufacture—can be used in place of our "protein-free milk" so as to raise animals to maturity without any other source of protein or inorganic salts. These observations pave the way for extending to other and larger species of animals the study of the problems which we are investigating with the rat.

Precisely as the use of zein has made it possible to ascertain certain quantitative features regarding the needs of tryptophane and lysine, feeding experiments with gliadin from wheat have enabled us to obtain additional information with respect to the physiological requirement for lysine, in which this protein is deficient. The extent of growth can be almost completely controlled at will from day to day by the quantity of a single factor, lysine, which is furnished in the diet.

These experiments with "deficient" proteins have led to the extension of our investigations to gelatin, from which tryptophane, tyrosine, and cystine are missing and in which phenylalanine and glutaminic acid are apparently present in very small proportions. The experiments in this direction may enable us to learn something regarding the part played by these other amino-acids in nutrition. An animal can be maintained for long periods without loss of body-weight on a diet devoid of lysine; such maintenance is impossible when tryptophane is missing in the food. It would seem, therefore, as if the need of lysine (if there be any) in the wear-and-tear or maintenance functions can be supplied from the reserves in the tissues more readily than the requirement for tryptophane can be thus satisfied. If, as now seems probable, new protein can not be synthesized unless the food furnishes lysine, the actual destruction of tissue protein in maintenance must be far smaller than it is currently believed to be. One of several experiments may be cited in support of these statements. A young rat weighing 50 grams was maintained on a zein-tryptophane diet at constant weight for six months, during which time it remained active and apparently in fair physical condition. Although body-weight was maintained, the animal grew extremely thin and showed every indication that its musculature was being drawn on to supply the deficiencies of the diet. The amount of lysine which could thus be furnished for the synthesis of new protein required for the maintenance of the physiological functions was manifestly small. Thus if we assume that 25 per cent of the animal is protein, yielding all of the amino-acids required for the synthesis of new protein, the total protein available during the six months was only 12.5 grams. Since only a small part of this 12.5 grams was actually used, and since presumably no new protein could be made from the zein-tryptophane food, it is nearly certain that the wear-and-tear quota of protein is extremely small. Our experiments have further indicated that food protein serves some further purpose than to furnish the amino-acids for the synthesis of new protein to

replace that destroyed in maintenance or used for tissue construction in growth. Thus young rats can for a long time be well maintained on a food with only 2 per cent of lactalbumin; but if this is reduced to 1 per cent they decline quite as rapidly as on the same diet free from protein and far more rapidly than on a tryptophane-free diet containing zein.

Investigation of the protein minimum by the use of diets containing different proportions of an individual protein has furnished an explanation for the unlike minima for maintenance and growth, respectively, which various investigators of this much-debated problem have reported hitherto for different types of dietaries. The interesting fact has already been brought out that the minimum protein requirement for maintenance is widely unlike in the case of different proteins because of their unlike yield of essential amino-acids. For example, with rations of a certain type less than 3 per cent of lactalbumin serves to maintain nutritive equilibrium as exhibited by stationary body-weight. The same proportion is far too small where either casein or edestin serves as the protein. These latter can be made adequate by increasing the total quantity of protein and equally well by smaller quantities of protein if their amino-acid deficiencies are made good. In the case of casein the addition of cystine alone enables the organism to use a large proportion of the companion amino-acids in the protein for constructive or other functional purposes without waste.

The discovery of methods of stunting animals over long periods of time, for example, by feeding incomplete proteins in the ration, use of inappropriate non-protein components in the dietary, limited feeding of adequate diets, alternate exhibition of adequate and inadequate foods, has been followed up by an extension of our experiments in this field. The experiments regarding the capacity to grow after the suppression of growth, mentioned in our last report, have given results which disprove the widespread view that the capacity to grow, or growth impulse, is lost with age, independently of whether it has, or has not, functioned during the period actually associated with increase in size. Experiments are at present under way to determine for how long slow growth can be continued and whether or not under such circumstances full adult size will be ultimately attained. Hitherto most of our experiments in suppressing growth were limited to animals which had already attained a considerable size. We are now repeating these with much smaller individuals. Furthermore, experiments are under way to deaminate native proteins by chemical methods, so as to determine whether the product of this treatment will maintain an animal without growth, as do lysine-free proteins. It has been made probable by the work of others that in the process of deamination lysine is the only amino-acid destroyed. Our preliminary experiments indicate that this is the case. If these experiments are successful we shall be able, more easily than at present, to prepare foods on which growth can not

be made. The factors which center in the control of growth are now being tested in other laboratories—in part as the outcome of our experience in this field—with reference to the control of abnormal growths.

Attention has been devoted to the proportions of "protein-free milk" that are necessary or desirable in rations for various purposes. New experiments in which artificial mixtures made in imitation of the natural product from milk have been employed have furnished added evidence of the presence of something in the natural "protein-free milk" which we have as yet been unable to identify. The detection of these essential ingredients, if it become possible, may have an important bearing upon the so-called vitamine problem. It is occasionally possible to raise animals to a considerable size on a diet of purified protein, starch, sugars, purified natural fats, and artificial mixtures of inorganic compounds. In some cases animals have been maintained for so long a time as to lead one to doubt whether any undiscovered factors in the diet are really necessary; but success of this sort has, after all, been a rare exception. Whenever failure has resulted, the addition of the natural milk product has invariably restored the declining animal. The efficiency of our "protein-free milk" is apparently not impaired by boiling during the process of its preparation. The ash of the product, on the other hand, is in no way comparable with "protein-free milk" as a substitute to furnish the inorganic ingredients of the dietary.

From experiments with the by-products of the manufacture of milk sugar, as a substitute for our "protein-free milk," it seems not unlikely that large amounts of products peculiarly valuable in the nutrition of domestic animals, particularly during the periods of growth, are being continually wasted in this country.

Sufficient experience has been gained to show that our methods of feeding will permit us to approach the problem of the influence of heating on the nutritive value of milk more satisfactorily than has been the case in previous experiments. Brief periods of heating, such as are employed in ordinary pasteurization or sterilization, are without apparent detrimental effect on the growth of rats. Heating at 100° for more than an hour appears to deteriorate the milk. At any rate, in the limited number of our experiments, these heated milks have appeared inferior to unheated milk when they formed the chief basis of the diet.

The unique virtue of butter-fat in restoring animals that had failed on our earlier dietaries, which was briefly alluded to in the last report, has been subjected to continued study. Animals which have received milk fat continuously from the very early periods of growth have uniformly failed to show any nutritive decline. The significance of the fat component in the milk, in furnishing something essential for prolonged adequate nutrition, is further substantiated by comparisons which we have instituted between the use of foods prepared from desiccated

unskimmed and skimmed milk, respectively. Furthermore, foods made with desiccated skimmed milk, containing at best only traces of the milk fats, have proved much inferior to those made with desiccated whole milk, since they have led to nutritive failure in every case, though as a rule at a much later interval than is observed with our usual mixtures of isolated foodstuffs containing lard as the only fat. The decline can be at once stopped by the admixture of butter-fat to the dietary.

We have now raised a large number of rats to adult size and have maintained them far longer than a year in perfect health on a diet consisting of a single purified protein, or a mixture of two such proteins, together with starch, lard, butter-fat, and natural "protein-free milk." Some of these have produced normal young, which in turn have also thriven on the same food. These experiments emphasize the fact that the need for protein is essentially one for suitable amino-acids and that either variety or quantity in the protein aspect of the diet apparently serves merely to insure a suitable supply of all the essential ones.

The nutrition-promoting factor in the butter-fat, which seems to be so essential for long-continued normal growth, is not contained in that component represented by the solid glycerides least soluble in alcohol. By fractioning butter-fat we have now been able to demonstrate that the more liquid portions, or what we may term the butter oil, contain the effective ingredient. That it is not universally present in natural oils has also been demonstrated by the inability of fats like almond oil and olive oil to replace the butter oil in promoting resumption of growth. On the other hand, the fat of the egg-yolk and cod-liver oil are efficient in the same way as butter oil. The nutrition-promoting properties of cod-liver oil were tested in great detail, owing to the widespread popular and medicinal use of this product. Our experiments afford, we believe, direct evidence that cod-liver oil is something more than a mere nutrient. At present experiments are in progress to ascertain how much butter oil is necessary to prevent nutritive disaster, or to induce restoration where decline has resulted. The quantities appear to be surprisingly small, as little as 1 per cent of butter-fat in the diet sufficing for more than nine months to prevent the much earlier decline hitherto experienced when lard alone was used. Experiments are also in progress to test the efficiency of the tissue fat of the cow in comparison with the fat of the mammary secretion. Beef fat now appears to be not entirely devoid of the advantageous properties found in butter-fat. Many of the experimental animals develop an infection of the eye during the periods of their nutritive decline. This has been noted by other investigators. The simple addition of butter-fat or cod-liver oil to the diet without other change leads to a prompt disappearance of the eye disease.

Professor L. F. Rettger, who earlier cooperated with us in studying the intestinal bacteria of the rats on our experimental dietaries, has

shown that soon after the diet is changed from the ordinary mixed food to the special diet containing starch, lard, protein-free milk, and a pure protein, the intestinal flora becomes so simplified that fewer types of bacteria are present. An increase in the number of gram-positive organisms is frequently observed. No appreciable differences in the bacterial flora have been observed after feeding various individual pure proteins with the exception of zein. Two organisms related to the acidophilous group of bacteria, which are found in the feces of the stockroom rats in relatively large numbers, are frequently present in the feces of the experimental rats to the exclusion of all other types, except *Bacillus bifidus* of Tissier and *Bacillus coli*. *B. bifidus* is much more abundant during the experimental feeding than with mixed food. On the former the number of *B. coli* is greatly reduced. No definite relationship was established between the bodily conditions (growth, vigor, etc.) and the intestinal flora of the rats receiving the special diets.

The absence of indigestible material from our dietaries has furnished an exceptional opportunity for studying the composition of the feces resulting after the ingestion of pure nutrients. The experiments demonstrate that a very considerable part of the fecal matter is made up of bacterial cells and that, with exception of zein, the proteins are very completely utilized.

The preparation of large quantities of the milk proteins, "protein-free milk," and butter-fat has led to the detection of the presence of several hitherto unnoticed constituents of milk which demand extended study.

To insure against the loss of our now valuable breeding-colony of white rats (by infection, fire, or other disaster) a branch colony has been established in the laboratories of the Sheffield Scientific School. These colonies are furnishing data regarding the average span of life of rats kept under the laboratory conditions with which we are dealing, so that suitable criteria as to what may be expected of any prolonged dietary program shall be established. Incidentally our experience has shown what can be accomplished by hygienic methods in the breeding of experimental animals. It has been gratifying to be able to cooperate with investigators in various parts of the country in furnishing experimental animals and, to a limited extent, special feeding products.

The study of the anaphylaxis reaction produced by carefully purified preparations of vegetable proteins has been continued in cooperation with Professor H. G. Wells and Mr. G. C. Lake and has been extended to the complement-fixation reaction, the formation of precipitins, and the production of passive anaphylaxis.

It was found that the antisera produced by a brief immunization gave the complement-fixation reaction only with the homologous protein. By more prolonged immunization the reaction took place with heterologous proteins of similar chemical and physical properties. At about

the time the complement-fixation reaction occurred the precipitin and passive anaphylaxis reactions appeared, but were at first limited to the homologous protein.

Further experiments with various proteins strongly suggest that the severity of the anaphylaxis reaction is proportional to the solubility of the proteins in the peritoneal solution. Proteins like edestin, which are precipitated on injecting into the peritoneal fluid, are so slowly redissolved that the animal rarely reacts fatally, whereas very small quantities of those vegetable proteins which are freely soluble in the peritoneal fluid cause fatal reactions. Thus, from 5 to 10 milligrams of most of the vegetable globulins were required to produce severe intoxication, but from 0.05 to 0.10 milligram of the so-called "vegetable proteoses" caused severe reactions and 0.5 to 2.0 milligrams gave fatal results. The alcohol-soluble proteins, gliadin and hordein, are more toxic than any of the vegetable globulins of the series tested. Since the proteoses formed by enzymatic or acid hydrolysis of native proteins do not cause anaphylactic intoxication, it is probable that most of the so-called "vegetable proteoses" should not be thus designated. The high toxicity of these substances corresponds with that of the native proteins and indicates that the "vegetable proteoses" have a similar, highly complex chemical structure.

We have also cooperated with Dr. Benjamin White and Dr. O. T. Avery in studying the immunity reactions of edestin and gliadin. This study has shown that edestin, in even small amount, agglutinates the red blood corpuscles of sheep or man, whereas gliadin does not. The serum of rabbits immunized with edestin contains a precipitating antibody for edestin, but not for gliadin. Edestin, in the presence of edestin-immune serum, completely binds complement, but gliadin, under these conditions, does not. In agreement with Dr. Wells's results the minimum sensitizing dose of edestin was found to be 0.0000001 gm., injected intraperitoneally into guinea-pigs. When 0.0500 gm. of edestin is subsequently injected *intraperitoneally* into animals thus sensitized they die quickly. If the sensitizing dose was 0.0001 to 0.0050 gm., 0.5 milligram of edestin, given *intravenously*, produced typical anaphylactic death in from two to six minutes. Guinea-pigs sensitized with edestin gave no reaction when the globulins of the squash-seed, castor-bean, or hazel-nut were intravenously injected, but reacted with large doses of the globulin of the flax-seed. Guinea-pigs born of a mother sensitized with edestin were also sensitized, but to a less degree than the mother. Passive sensitization to edestin appeared to be somewhat greater than that induced by active sensitization. Edestin hydrolyzed by the Vaughan method yielded a substance which caused an apparently true anaphylactic shock. Edestin yields a toxic product which appeared to correspond to the anaphylatoxin of Friedberger.

PALEONTOLOGY.

Case, E. C., University of Michigan, Ann Arbor, Michigan. *Completion of the work on the Permian vertebrate fauna of North America.* (For previous reports see Year Books Nos. 2, 4, 8–12.)

The field season of 1914 was spent in a study of the Red Beds exposed in the Black Hills, Laramie region, Hartville Uplift, and the foot hills of the Rocky Mountains, visiting the type localities of these beds and making a careful comparison of the deposit with the Red Beds of Texas, Oklahoma, and Kansas.

The especial object of this work was to determine the relation of the northern beds to those of the south and to determine, so far as possible, the conditions under which they were deposited. The main questions, which it is believed may be answered affirmatively, were whether the northern Red Beds are a part of the same area of deposition as those exposed in the south and whether there were two distinct areas of deposition, more or less contemporaneous, one to the east of the Rocky Mountain axis and one to the west.

Hay, Oliver P., U. S. National Museum, Washington, District of Columbia. *Investigation of the vertebrate paleontology of the Pleistocene epoch.* (For previous reports see Year Books Nos. 11, 12.)

After the last annual report was prepared the writer continued his investigations on the Pleistocene Vertebrata of North America and their relations to the various stages of this epoch. During the latter part of 1913 some time was consumed in studying the extinct bisons; the results were published in the Proceedings of the United States National Museum. Later the camels of the extinct genus *Camelops* were investigated and a paper thereon was published, likewise in the Proceedings mentioned. The months of January and February were spent in visiting the collections contained in various museums, universities, colleges, scientific academies, and in private hands. All together about forty collections were examined, located in northern New York, northern Ohio, southern Michigan, northern Indiana; in Milwaukee, Wisconsin; Mankato, Minnesota; many towns in Iowa; at Lincoln, Nebraska; Kansas City, Columbia, and St. Louis, Missouri; and at Greenville, Ohio. A considerable amount of valuable material was seen and studied. In the museum of the Firelands Historical Society, at Norwalk, Ohio, were found some parts of the skull of an undescribed extinct bison, the only extinct species of the genus known to have existed after the disappearance of the last glacial ice sheet.

Since the first of March the writer has been engaged in further study of horses. In a collection, now in the United States National Museum and made many years ago near Hay Springs, Nebraska, there is the nearly complete skull of a large extinct horse closely resembling the

larger breeds of the domestic horse. From Texas has been received, for examination and description, a nearly complete skull and many parts of the skeleton of a small horse. The study of these materials led to the study of the measurements and indices which are relied on to establish the composite origin of the domestic horses. From Elephant Point, Alaska, there was sent to the United States National Museum, many years ago, a part of the skull of an undescribed species of musk-ox. Detailed descriptions of these new species and discussions of their relationships are ready for publication.

A paper on the Pleistocene epoch of Iowa and its mammals will soon be published as a part of volume 22 of the Iowa Geological Survey. Although a mass of data has been accumulated and a number of maps have been prepared or are in course of preparation, much remains to be done before a final report can be made on the subject under investigation.

Wieland, G. R., Yale University, New Haven, Conn. *Continuation of investigations on fossil cycads.* (For previous reports see Year Books Nos. 2–4, 6–9, 11, and 12.)

The activities of the present year have been confined solely to work on the fossil cycads and to bringing together usable laboratory equipment. That now at hand, as supplemented by Yale University facilities, may fairly be called superior. In fact, there are few immediate needs unprovided for or that can not be readily met from present funds.

The private laboratory unit at Anawan, West Haven, Connecticut, mentioned in last year's report, is provided with water, gas, and electricity, and is especially suited to and well equipped for scientific photography and the sawing of thin sections—blocking-out work. As yet no attempt has been made to improve apparatus for grinding and polishing, although plans for bettered equipment have been considered, and can be effectively carried out at any time when desirable. It is wished to avoid the duplication of any installations more appropriately falling within the province of existing large institutions.

Meanwhile field study and collection of Mesozoic cycads, more than ever desirable to carry out, have lapsed for various other reasons than nearly universal war. However, now that it has been possible to provide for carrying forward quite every phase in the elaboration of material with relative ease and speed at all seasons, a large part of every succeeding year, during which these studies are continued, will be devoted to field study.

Further assurance of the publication of the awaited volume on the Liassic flora of the Mixteca Alta has been given by Señor Aguiléra, Director of the Mexican Geological Survey, and it is trusted that this well-illustrated work may soon appear.

The supplementary volume to Carnegie Institution Publication No. 34 has taken longer to bring into final form than was at first anticipated, owing to the difficulty of placing artificially defined species in

many cases where required sections are simply not available in the present phase of study. But it is wished to offer this work for publication within the present year, and it is confidently trusted that any lack in taxonomic completeness will be fairly made up for in biologic interest. As already known to those who have followed previous reports and various preliminary papers, the Cycadeoideæ have a far more varied and interesting floral structure than was at first supposed.

With reference to a better taxonomy of the silicified cycads, it should, however, be emphasized that the attempt to determine the full structural characters and specific variations within the group has been by no means abandoned. On the contrary, a more insistent and determined effort is being made to reach final taxonomic accuracy.

The most important result of the year has been the description of more completely conserved flowers the structure of which clearly suggests the actual mode of origin of the early gymnosperm seed coats. A preliminary treatment of this fundamentally important subject, indicating a dual homology between seed and flower, and for the first time perhaps breaking real ground for eventual progress in the study of floral evolution, has already been published. (*Cf.* Bibliography.)

PHILOLOGY.

Loew, E. A., Oxford, England. *Continuation and completion of researches and publication of the "Scriptura Beneventana."* (For previous reports see Year Books Nos. 9–12.)

Three months were spent in compiling a catalogue of the extant manuscripts in Beneventan writing, and this catalogue, which includes over 600 items, was published as an appendix to the "Beneventan Script." This work, which gives a comprehensive treatment of the South Italian minuscule, upon which I have been at work for several years, appeared in April of this year, as an Oxford University publication.

During April and May I was in Germany, where I continued investigations begun last year upon the manuscripts written in the ancient writing-center of Würzburg, most of which are still preserved in Würzburg. The work proved interesting beyond expectation; for the great majority of the oldest manuscripts of Würzburg are written in the Irish and the Anglo-Saxon scripts of the eighth and early ninth centuries and are thus the clearest possible evidence of the prominent part played by the Irish, and especially by Anglo-Saxon clerics (St. Boniface and his followers) in the culture of that part of Germany. I have been able to obtain photographic reproductions of all the most important manuscripts and these will serve as material for a publication.

After leaving Germany, I made a short stop at Paris, where I re-examined the so-called "Bobbio Missal," which is not only one of our oldest liturgical documents, but is also of great paleographical interest. Upon this manuscript, consisting of 600 pages, I have been at work since

my return from Germany. A complete transcription of it, accompanied by a paleographical introduction, is being prepared for publication.

The latter part of 1914 will be taken up with revising and publishing the letterpress to go with the collection of plates entitled "Scriptura Beneventana." The collotype facsimiles have already been printed. In the autumn I shall have the honor of delivering the Sandars lectures—four in number—before the University of Cambridge, and seven lectures on the history of Latin writing before the University of Oxford.

PHYSICS.

Barus, Carl, Brown University, Providence, Rhode Island. *Study of diffusion of gases through liquids and provision for applications of the elliptic interferometer.* (For previous reports see Year Books Nos. 4, 5, 7–12.)

In the early part of the year, Professor Barus continued his experiments with the quadrant electrometer, made specially sensitive by providing the needle with two light, symmetrically parallel plane mirrors, about 5 centimeters apart. One of the component beams of the displacement interferometer, impinging at an angle of about 45 degrees, passes from the first mirror to the second, thence to the distant fixed mirror, from which it is normally reflected and returns in its path. It should be possible, in a quiet laboratory, to measure voltages as small as 10 micro-volts per vanishing interference ring, so that single micro-volts could be reached by estimation. In the large number of experiments made, the optical adjustment presented no serious difficulty. It was found exceedingly troublesome, however, to adapt the behavior of the electrical apparatus to the same degree of sensitiveness.

Throughout the year the application of the displacement interferometer to the horizontal pendulum has been the chief subject of investigation. A number of methods were devised and tested in detail, among which was the above method of two parallel mirrors, on a symmetrical pendulum beam, loaded on one side. With the mirrors a meter or more apart, the sensitiveness is correspondingly increased. It is simpler, however, to replace the two opaque mirrors of the interferometer by two identical concave mirrors, having their foci at the grating. If the focal distances are large enough, say 1 meter or more, the grating may then be rotated on its axis as far as the mirrors will allow (several degrees), without seriously disturbing the interferences. This is in excess of anything required by the horizontal pendulum. If, then, the rotational defect is eliminated, the displacement of the end of the horizontal pendulum may be measured as usual. The apparatus with which the measurements were made was built for experimental purposes and not for extreme refinements; but with the grating at 111 cm. from the nearly vertical axis of the pendulum, the horizontal angle corresponding to a vanishing interference ring was 0.028″. Hence, for an inclination of the axis to the vertical of about 0.6°, the

corresponding change of this inclination would be less than 3×10^{-4} seconds of arc. The surroundings of an ordinary laboratory are not of a kind to warrant results to this degree of precision; but continuous observations were nevertheless carried out with two instruments (one attached to a pier, the other to the concreted sub-basement) for the purpose of studying their behavior. In one casethe pendulum was all but supported on a cylindrical float. If this is placed symmetrically to the axis, it does not change the sensitiveness, but it relieves the pivots of friction, on the one hand, and serves as an adequate damper on the other. A variety of interesting results were obtained with this apparatus. To increase the sensitiveness the float would have to be attached at the center of gravity. In many of the measurements the ruled-glass grating was replaced by a film grating. In this case the initial adjustment is difficult; but once obtained, the subsequent work proceeds as well as with the ruled grating.

In view of the small rotations measurable in this way, the apparatus is available for measuring correspondingly small variations of torque, while on the other hand it has sufficient strength to support relatively large loads. It was therefore intended to measure the gravitational attraction of two disks, since, if they are all but in contact, the attraction, for a constant mass, may be estimated to increase roughly as the fourth power of their radii. On trial, however, the disks were found actually to repel each other, with forces much in excess of their gravitational attraction. Plates of brass, 20 centimeters in diameter and about 1 millimeter apart, showed repulsions of the order of 0.5 dyne, which is equivalent to a pressure excess of about 10^{-9} atmosphere. It is much larger than such electrical repulsion as might be ascribed to the absolute voltaic potential of the disks. It persists after the accumulation of air (due to the viscosity of the film of air between the disks) should have been dissipated. The forces in question, moreover, may be determined by charging the plates to definite differences of potential. So far as can be seen at present, the repulsion is due to the condensation of air at the surface of the plates, by molecular attraction, so that the investigation of these forces, for different distances, should be of considerable interest.

In a different class of experiments, and with the object of testing the limits of the equations assumed, the refraction of glass columns 25 centimeters or more in length was investigated for different colors of the spectrum. It was at first expected that when such long columns are inserted into one of the interfering beams the change of the index of refraction with wave-length would be measurable with exceptional precision; but this anticipation was not realized in full, as the amount of shifting of the ellipses per unit of length of the compensating micrometer-screw decreases with the length of the column. The equations were found to reproduce the observations accurately. It was necessary

to build up the columns by cementing plates of glass together. No long rods of glass tested were sufficiently homogeneous to be available.

An earlier report on the coronas of cloudy condensation shows that on using homogeneous mercury light, the maximum of green illumination is found alternately in the disk of the corona and in the first green ring, as the particles increase in size successively. This superposition of an independent periodicity contains the key to the optics of coronas; experiments were therefore made at some length to utilize these observations for the practical case of the green coronas and white light.

Finally, the experiments on the diffusion of gases through liquids were continued, particularly in the direction of diffusions through solutions of different strengths and composition. Apparatus was also installed for observing the diffusions of a gas through the unequal columns of a liquid, in a sealed tube, in the lapse of years.

Hayford, John F., Northwestern University, Evanston, Illinois. *Investigation of the laws of evaporation and stream flow.* (For previous report see Year Book No. 12.)

The general plan of the investigation of evaporation is to consider each of the Great Lakes in turn as an evaporation pan, to evaluate the income, outgo (other than evaporation), and change of content of the lake day by day as accurately as possible, and from these evaluations to determine the daily evaporation and its relation to meteorological conditions. The change of content of each lake from day to day is determined by the change in mean level of the water-surface. The level on Lake Michigan-Huron, for example, is observed by automatic gages at Harbor Beach, Mackinaw City, and Milwaukee, maintained by the survey of the Northern and Northwestern Lakes, which continuously record the water-level at these points. To derive from any one of these records at a single point the fluctuation of the mean surface of the whole lake, with the degree of accuracy necessary for this investigation of evaporation, one must be able to correct the record at the gage for the effects of winds and of barometric changes. The winds tend each day to lower or to raise the level of the water-surface at the gage independently of any change which may have taken place in the total content of the lake. The principal attack of the past year in the least-square solution has been upon the problem of determining with sufficient accuracy the local effects at the gages of wind changes and barometric changes, and of correcting for these local effects in the computations from which the evaporation constants are to be derived. This particular problem has proved to be more difficult of satisfactory solution than it was supposed it would be. Progress is being made, though but slowly. The evaluation of wind effects and barometric effects bids fair, however, to be an unexpectedly valuable by-product of the investigation.

At this stage of the investigation, when it is little more than half completed, as measured by the cash expenditure, it is premature to

estimate the degree of success, except to state that at least a partial success is certain. No attempt has thus far been made to study stream flow, as that portion of the investigation is intended to be based on more information in regard to evaporation than is now available.

Howe, Henry M., Columbia University, New York, N. Y. *Investigation into the heat treatment of steel.* (For previous reports see Year Books 6–12.)

While most of the year has been spent in collating and digesting the existing information on the subjects in hand, with a view to publication in a treatise of which the first volume is now nearly ready, a considerable amount of direct experimental work has been done. This is recapitulated as follows:

1. Overstrain.

Steel is a conglomerate of different structural constituents. The relative movements of these constituents and their general behavior during plastic deformation have been studied, by means of the changes which this deformation brings about in their arrangement and the simultaneous changes in hardness and density. The deformation has been brought about in some cases by tensile rupture, and in others by punching. In addition to many other inferences of detail, it is found that the polish which the upper part of a vertically punched hole shows is due to the radial pressure of this part of the metal against the entering punch, after its end has passed beyond this part. The metal combines with a degree of viscosity which results in the retention of very great internal pressure in the region near where the punch is forcing its way, a degree of mobility which enables this pressure to act in every direction. Among these directions is one radially and towards the punch. This component of the pressure acts like the pressure in a hydraulic cylinder which tightens the packing about the plunger, and thus forces the metal in the already punched upper part of the hole against the still descending punch so firmly that the movement of the punch now causes the high polish observed.

Further, though the lamellæ of pearlitic cementite are extremely brittle, they may be crumpled into W and V shapes by the deformation and still retain continuity. This may be referred to their thinness, as thin enough glass hairs can be bent far without breaking.

Pearlite masses consist of alternate lamellæ of the very ductile plastic ferrite with very brittle cementite. When they are elongated parallel to the stratification the cementite lamellæ simply break up into shorter fragments; when they are shortened parallel to the stratification their arrangement changes, militarily speaking, from close order in line to open order *en echelon*.

From the fact that the effects of repetitive overstrain are extremely anisotropic, it has been currently inferred that those of single applications of overstrain also are; but my experiments show that the increase

of hardness caused by tensile rupture in low-carbon steel of 0.11 per cent of carbon is isotropic, within the limits of observational error.

2. Pearlite Divorce and Related Subjects.

The study of the divorcing of the carbon-iron eutectoid pearlite has been pursued. Though divorce is the more rapid the larger the quantity of the free or pro-eutectoid element present, yet it occurs, though slowly, even in the complete absence of this element. It is opposed by either long or high prior heating. It is promoted and opposed by minor causes difficult to detect, so that the degree of divorce varies greatly between adjoining areas in any given specimen. Divorce softens and ductilizes the steel, but at a disproportionate loss of maximum and elastic tensile strength. It affects these properties of very low-carbon steel only slightly. It lessens the impact resistance of notched specimens, but this effect is slight in the case of eutectoid and hyper-eutectoid steels.

The size of the grains of ferrite of an un-overstrained steel increases at temperatures within the transformation range, contrary to general belief.

The experiments throw doubt on the general belief which connects the Widmanstättian structure with the rate of cooling. They show that the stability of this structure is very great.

Nichols, E. L., Cornell University, Ithaca, New York. *Systematic study of the properties of matter through a wide range of temperatures.* (For previous reports see Year Books Nos. 4–12.)

For the more complete study of the fluorescence and absorption of the uranyl salts we have had samples of 25 different compounds specially prepared by Mr. G. O. Cragwall, of the Department of Chemistry of Cornell University, with particular attention to the utmost attainable purity. These have been investigated at the temperature of liquid air and their fluorescence spectra photographed by methods already described.

The spectra are without exception less complex than those obtained from the salts from Kahlbaum previously studied, and in the four instances, *i. e.*, UO_2SO_4, $UO_2(NO_3)_2$, UO_2Cl_2, and $UO_2\ SO_4.K_2SO_4$, in which the preparations of Cragwall and those from Kahlbaum were supposed to be of identical composition, we find identity of position as to the more prominent series, but that a bewildering mass of lesser bands are absent in the new samples.

The photographs of the Cragwall preparations have all been measured, many of them both on the comparator and by projection, and the data are now being studied with a view to possible relations between the frequency intervals and molecular weights; also to determine the effect of physical condition, etc.

In the preparation of the uranyl chloride a form of this salt was obtained consisting of well-crystallized, non-hygroscopic, tri-clinic plates. These when excited at the temperature of the room exhibited a brilliant fluorescence spectrum of striking symmetry, which instead of the usual group of seven or eight bands was resolved into eight groups, each consisting of five very narrow, nearly equidistant bands, the arrangement of which repeats itself with exactness in each group. This remarkable spectrum has been studied in detail at various temperatures between +20° and −185° C. and the results will be described at length in a forthcoming number of the Physical Review.

The preliminary study of the fluorescence of frozen solutions of the uranyl salts, referred to in Year Book No. 12, has been completed, and the results have been published in the Physical Review (second series, vol. III, p. 457). The detailed investigation of the complicated effects observed when fluorescence is excited under varying conditions as to dilution and temperature has since been completed by Mr. H. L. Howes and his determinations are now being prepared for publication.

The investigation of the decay of phosphorescence at low temperatures by Dr. E. H. Kennard has been completed and is published (Physical Review, second series, vol. IV, p. 278). He finds the linear relation between time and the reciprocal of the square root of the intensity to hold for cetyl alcohol and kerosene, but that in the case of paraffine the decay during the later stages increases in rapidity with time and that the intensity of phosphorescence is expressed, within the errors of observation, by the equation

$$I = \frac{I_0 \, e^{-\beta t}}{[1 + \frac{a}{\beta}(1 - e^{-\beta t})]^2}$$

During the year covered by this report quantitative studies have been completed on the luminescence of kunzite (Nichols and Howes, Physical Review, second series, vol. IV, p. 18).

The red and blue bands in the fluorescence spectrum, at 0.590μ and 0.432μ, previously described by Pochettino, were located and mapped, together with the associated bands of absorption. The relative brightness of the two bands in the case of pink and of white kunzite was determined and the effect of temperature on the form and location of the red band was noted. The study of the phosphorescence of the red band after kathodo-bombardment brought out a law of decay not hitherto definitely established for any phosphorescent substance. An initial (so-called "linear") process of very short duration was found to precede the two such processes commonly observed.

Dr. Frances G. Wick, an account of whose investigation of the fluorescence, absorption, and surface color of the platino-cyanides has been published in the Physical Review (second series, vol. III, p. 382), made observations during the summer of 1914 on the fluorescence

spectra of the uranyl salts when subjected to the exciting action of X-rays. The identity of these spectra with those obtained by photo-excitation was established, but it was found that these substances, which when excited by light show no luminous after-effect of appreciable duration, are strongly phosphorescent under X-rays, with a decay unusually rapid at first but followed by a faint glow of long duration.

Mr. C. E. Power has completed his study of the phosphorescence of certain of the Lenard and Klatt sulphides, at temperatures up to the point of final extinction, and his data are nearly ready for publication.

Dr. R. C. Gibbs and Mr. K. S. Gibson have further extended their long-continued series of measurements of the absorption of light by various colored glasses for temperatures between 400° C. and −180° C. They have also investigated in detail the fluorescence and absorption of synthetic ruby throughout the same range of temperature and have studied the fluorescence and absorption of a series of organic compounds recently prepared and studied from the chemical standpoint by Professor Orndorff, of Cornell University.

These substances, ten in number, which were obtained by loading the molecule of α, β, and γ orcinol-phthalein with chlorine or bromine, show consistent and systematic shift of the absorption bands, and, in the case of the γ group, of the fluorescence bands also, towards the longer wave-lengths as the load is increased.

Mr. H. E. Howe has been working upon the same group of substances, using the quartz-spectrograph, and has discovered and mapped a set of absorption bands in the ultra-violet which extends as far as 0.20μ. The effects of change in the arrangement and composition of the molecule are found to be similar to those observed in the visible spectrum.

Dr. C. C. Bidwell's measurements of the radiation from metal surfaces and his studies of the thermo-electromotive properties of various metallic oxides have been published since the appearance of Year Book No. 12 (Physical Review, second series, vol. III, pp. 204, 439, and 450). He is continuing his investigation of the properties of these interesting compounds.

An account of Dr. A. K. Ångström's observations on the selective reflection from solutions in the infra-red has been given in the Physical Review (second series, vol. III, p. 47). He finds:

(1) That the reflection maximum of water at 3.20μ is shifted to the longer wave-lengths when the strongly hydrated salts $CaCl_2$ and $SrCl_2$ are present.

(2) That no appreciable shift is produced by the solution of NaCl, Na_2SO_4, KNO_3, or $CuSO_4$.

(3) That the reflection maximum is considerably shifted towards the longer wave-lengths when a true hydrate NaOH, KOH is in solution.

(4) That concentrated sulphuric acid shows the reflection maximum characteristic of the OH group.

(5) That this maximum tends to vanish when the molecule is broken down through dissociation.

PHYSIOLOGY.

Reichert, E. T., University of Pennsylvania, Philadelphia, Pennsylvania. *Continuation of study of differentiation and specificity of corresponding vital substances.* (For previous reports see Year Books Nos. 9–12.)

During the past year further improvements have been made in the methods of investigation. The work has been limited almost to the study of the starches and certain other products of parent stock and offspring, and the results have been qualitatively and quantitatively entirely satisfactory. It is expected that this investigation will be completed some time during the coming spring.

PSYCHOLOGY.

Watson, John B., Johns Hopkins University, Baltimore, Md. *Research Associate of the Department of Marine Biology.* (For previous reports see Year Books Nos. 6, 9, 11, and 12.)

During the summer of 1914 the experiments on the acquisition of skill in archery, begun in Tortugas in 1913, were completed by Dr. K. S. Lashley, of the Johns Hopkins University. An archery range (40 yards) was constructed in the open. The specific object of the experiment was to test the effect upon the acquisition of skill of different amounts of daily practice. Twenty untrained subjects were divided into three groups. One group shot 5 arrows with the English longbow per day; another, 20 shots per day; and the third, 40 shots.

The results of the experiments show quite conclusively that the group shooting only 5 times per day improved in accuracy with less expenditure of time in practice than was required by either of the other two groups for the same amount of improvement. No appreciable difference appeared in result of practice distributed in 20 or 40 shots per day. The relatively greater efficiency of short periods of practice continuing for many days is in accordance with the results of the study of animals and of speech habits in man, and indicates that in training to muscular feats, both animals and man, the length of practice periods required is usually too great for maximum efficiency.

Professor Watson is continuing work on the homing pigeon along two lines: First, the sensitivity of the pigeon to infra-luminous rays is being tested by a method similar to that employed with the chick, only in this case the method has been refined (see 1913 report of investigations from the Marine Biological Laboratory). In the second place, the sensitivity of the homing pigeon to differences in (*a*) pressure, (*b*) temperature, and (*c*) moisture of two air columns is being tested by a physiological method. The pigeon is saddled comfortably in such a way that respiration can be graphically recorded. Changes in the rate, amplitude, and form of respiration are used as indicators of sensitivity to the stimuli employed. In order to make the respiratory curve stable, decerebrated pigeons will be used as controls.

ZOOLOGY.

Castle, W. E., Harvard University, Cambridge, Massachusetts. *Continuation of experimental studies of heredity in small mammals.* (For previous reports see Year Books Nos. 3–12.)

The problems upon which my studies are centered and the methods adopted for attacking them were so fully outlined in Year Book No. 12 that I shall confine myself in the present report to stating the progress which has since been made. As then reported, several extended investigations had reached a point warranting full publication. Accordingly the past year has seen greater activity than usual in this direction. Publications No. 195 and 196 have been issued. Dr. Detlefsen's work on guinea-pig hybrids is in process of publication, and fifteen shorter papers have been published by Drs. Little, MacDowell, Phillips, and myself, dealing with or closely related to the work carried out under this grant.

New work undertaken relates chiefly to the stocks of guinea-pigs, wild, feral, and domesticated, obtained from Peru in the expedition of 1911. In this I am being assisted by Mr. S. Wright. This material is yielding interesting results, among which may be mentioned the discovery of color stages intermediate between the pigmentation of ordinary mammals and albinos, all of which fall into a single series of allelomorphs. It is a good illustration of what Bateson has called fractionation of a Mendelian character.

Dr. Phillips having, during the past year, been absent on zoological expeditions or engaged in extensive breeding experiments with ducks and pheasants at his home, has been unable to give further attention to the breeding experiments with rats which we had carried on jointly for several years. Accordingly I have made the rat experiments my own immediate and principal object of study. New all-metal cages have been installed and the feeding and caretaking have been simplified and systematized. In attempting to devise a standard ration for laboratory rats, I have had valuable assistance from Professors Osborne and Mendel.

Riddle, Oscar, Cold Spring Harbor, Long Island, New York. *Preparation for publication of the manuscripts of the late Dr. C. O. Whitman, provision for care and maintenance of the Whitman pigeon collection, and continuation of investigations necessary for completion of Dr. Whitman's manuscripts.* (For previous reports see Year Books Nos. 11, 12.)

During the year a large part of Professor Whitman's data on breeding and sex, and on "strength" and "weakness" of germ-cells, have been summarized, tabulated, and made ready for publication. This work has required the repeated inspection of the entire body of records and manuscripts. The manuscripts on "behavior," in the hands of Pro-

fessor Harvey Carr, of the University of Chicago, are nearing completion and will soon be submitted for publication.

The Whitman pigeon collection has been transferred from Chicago to the Station for Experimental Evolution at Cold Spring Harbor. In numbers and in species the collection is hardly as strong as formerly, though in some respects it has been strengthened and is at present in very favorable condition.

New studies on a comparison of the amount of stored energy in the male and female producing yolks have been carried on with the bomb calorimeter during the present year. The results fully confirm earlier and simultaneous conclusions reached upon the basis of numerous chemical analyses. Male-producing ova store less energy than do female producing ova.

All of the previously reported lines of investigation on sex and sex control in pigeons have been continued on an increased number of individuals and the earlier results have been extended and confirmed. All these investigations will be continued for another year. Throughout the present year the sex-dimorphism of the ova has been followed in 113 females; these individuals representing 2 families, 4 genera, 10 species, and 8 kinds of hybrids. Many of these individuals have been continuously studied since 1911. The results conclusively show that doves produce two kinds of eggs—different in size and in their relative tendency to produce male and female. The studies on the sex behavior of doves from a sex-controlled series, and on the modification of this by the injection of germinal extracts, have now furnished the most striking and convincing evidence, not only of the reality of sex-control, but of the quantitative nature and basis of sex itself.

Naples Zoological Station, Naples, Italy. *Maintenance of two tables for American biologists.* (For previous reports see Year Books Nos. 2–12.)

During the last term the two tables of the Carnegie Institution of Washington were occupied by Professor Edwin C. Starks, of Stanford University, California, from January 13 to March 7, 1914, and by Miss Mathilde Lange, Leipzig, from February 2 to June 13, 1914.

Dr. Starks was engaged in continuing his studies on the osteology and myology of various little-known Acanthopterygians.

Miss Lange worked on the regenerative power of Cephalopods and was supplied with abundant material. She investigated particularly *Octopus*, *Eledone*, and *Sepia* (young and adult). The studies referred particularly to the regeneration of the arms, but she obtained also some results on the regenerative capacity of the eye. The regenerated organs were preserved, but their histological investigation was only partly done in the laboratories of the Zoological Station.

INDEX.